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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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THE JOURNAL

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THE ORBIT OF θ AQUILÆ

W. E. HARPER

THE star θ *Aquilæ* ($\alpha = 20^h\ 06{\cdot}2^m$, $\delta = -1°\ 07'$, photographic magnitude 3·6) was discovered to be a spectroscopic binary by M. Deslandres* in 1902. From the twenty-six plates secured he obtained a period of 16·7 days and eccentricity about 0·6. As the results obtained by him were regarded as only provisional the star was placed on our observing list here in May, 1907, when the single-prism spectrograph was ready for use. In all fifty-two measurable plates were secured that year and from these, preliminary values of the elements were obtained.† For convenience of reference these are given here.

$$P = 17{\cdot}17^d$$
$$\gamma = -26{\cdot}7 \text{ km.}$$
$$e = 0{\cdot}725$$
$$\omega' = 20°$$
$$T = 1907 \text{ October } 2.15 \text{ G.M.T.}$$
$$= J.\ D.\ 2{,}417,\ 851{\cdot}15$$
$$a \sin i = 8{,}455{,}500 \text{ km.}$$

As unfavorable weather prevented the securing of spectrograms in all its phases, particularly near the time of periastron

* *Bulletin Astronomique*, XX., 129, 1903.

† *Journal of the Royal Astronomical Society of Canada*, I., 357, 1907.

passage, work was resumed on it this year with the object of filling up any gaps in the curve. Forty-five spectrograms were secured this year and these have been combined with those of last year to determine the orbit. Some half-dozen plates of last year, in which the agreement among the various lines was not all that could be desired, were remeasured, but only two, Nos. 924 and 959, were changed in velocity appreciably. Plates 1038 and 1050, which had not been measured last year, are also added.

Four of the plates, Nos. 1001, 1100, 1101 and 1794, were made with the three-prism spectrograph, whose linear dispersion at H_γ is 10·1 tenth-metres per millimeter; the balance were all made with the single-prism spectrograph, which at H_γ has a linear dispersion of 30·2 tenth-millimeters per millimeter and gives the whole visible spectrum in sharp focus. The region used for velocity determinations is that lying between and including H_β and K. The plates used were Seed 27.

The spectrum is of the type VII. *a*, and in the portion used the *Mg* line (λ 4481) and K (λ 3933) are best defined. The hydrogen lines are fairly well measurable, especially H_γ, the line λ 4549 is fairly sharp as are also the silicon lines. In addition to those given in Table I. some faint metallic lines also appear in some of the plates. The velocities corresponding to one revolution of the micrometer screw (0·5 mm. pitch) are also attached.

TABLE I.

Lines in θ *Aquilæ*

Element	Wave-Length	Velocity per Revolution
H	4861·527	1451·
Fe	4549·642	1204·
Mg	4481·400	1151·
H	4340·634	1044·
Fe	4233·328	964·
He	4143·928	898·
Si	4131·047	889·
Si	4128·211	887·
H	4101·890	868·
H	3970·177	774·
Ca	3933·825	749·

Practically all the plates made have been used in the discussion, even although one or two have not been of the first quality,

No. 865 being a case in point. In the preliminary curve for this year ($P = 17{\cdot}120$) No. 873 gave an abnormally high residual (-28 km.), and following out a suggestion of Mr. J. S. Plaskett, to whom I am much indebted for help during this work, the result was omitted from consideration in the least-square solution, as an excessive residual tends to distort the elements out of all agreement with the mean values, as obtained from the remaining observations.

Table II. gives all the data of the plates, the phase being reckoned from periastron, Julian Day 2,417,731·504, using the period finally determined, 17·112 days.

The observations of 1907 and 1908 were grouped separately and the period which suited best was 17·120 days.* The phases for this period were computed, being reckoned from an initial epoch T_0, Julian Day 2,417,727, the date of the first observation. The observations of the two years were now combined and grouped into 18 normal places. Weights were assigned to these groups depending not only upon the sum of the weights of the individual plates but upon the number of nights involved. The maximum weight was taken as 5. In the weighting of the individual plates not only the quality of the plate *per se* but the agreement among the various lines was taken into account. The groups are given in Table III.

Using the graphical method* of Dr. King, various values of e and ω were tried, those finally decided upon as suiting the grouped observations best being $e = 0{\cdot}680$, $\omega = 20°$, $K = 49$ km. and time of periastron passage, T, 4·30 days from initial epoch. Thus for preliminary elements we have :

$P = 17{\cdot}120$ days
$e = 0{\cdot}680$
$\omega = 20°$
$T =$ Julian Day 2,417,731·30
$K = 49$ km.
$\gamma = -25{\cdot}3$ km.

* *Astrophysical Journal*, XXVII., 125, 1908.

Table II.

Measures of θ *Aquilæ*,

Plate No.	Julian Date	Phase	No. of Lines	Weight	Velocity	Residual
	1907					
803	2,417, 727·814	13·425	4	5	− 24·	+ 0·2
819	737·787	6·284	4	5	− 39·	+ 3·1
841	739·836	8·333	4	5	− 38·	− 0·4
854	741·813	10·310	4	5	− 42·	− 5·9
865	747·778	16·275	1	2	+ 45·	+ 16·0
905	759·777	11·162	5	4	− 40·	− 5·2
924	765·777	0·050	5	4	+ 30·	− 19·5
931	766·711	0·984	7	5	− 30·	+ 9·8
942	770·703	4·976	4	4	− 40·	+ 5·7
946	773·713	7·986	3	3	− 43·	− 5·0
959	777·764	12·037	5	3	− 40·	− 7·8
969	784·760	1·921	4	4	− 40·	− 1·8
1001	798·660	15·821	5	4	+ 19·	+ 6·2
1012	801·692	1·741	4	3	− 39·	− 2·0
1013	803·573	3·622	6	4	− 51·	− 4·1
1027	815·630	15·679	3	3	+ 10·	+ 1·1
1028	815·669	15·718	2	5	+ 11.	+ 1·0
1033	825·612	8·549	4	3	− 38·	− 0·6
1038	831·635	14·572	4	2	− 8·	+ 3·6
1043	833·673	16·610	7	3	+ 55.	+ 10·5
1050	837·614	3·438	4	4	− 47·	− 0·4
1072	849·543	15·367	5	4	+ 3·	+ 1·3
1073	849·559	15·383	4	5	+ 4·	+ 2·1
1074	849·589	15·413	6	5	− 7·	− 9·4
1080	850·502	16·326	3	2	+ 28·	− 2·6
1081	850·521	16·345	5	3	+ 33·	+ 0·8
1082	850·548	16·372	6	4	+ 30·	− 3·8
1085	850·613	16·437	8	5	+ 25·	− 10·5
1086	850·642	16·466	5	3	+ 36.	− 1·0
1089	851·528	0·240	5	4	+ 18·	− 12·0
1091	851·570	0·282	3	2	+ 28·	+ 0·2
1092	851·589	0·301	5	2	+ 23·	− 2·6
1093	851·605	0·317	5	3	+ 26·	+ 2·6
1094	851·625	0·337	2	1	+ 12·	− 9·0
1100	867·510	16·223	1	1	+ 28·	+ 1·7
1101	867·574	16·287	3	3	+ 33·	+ 4·0
1106	874·535	6·135	4	2	− 44·	+ 1·4
1128	884·437	16·038	5	5	+ 16·	− 4·0
1129	884·452	16·052	5	5	+ 32·	+ 11·6
1146	896·500	10·988	4	2	− 38·	− 2·8
1149	898·448	12·936	3	1	− 31·	− 3·4
1150	898·526	13·014	5	3	− 20·	+ 7·2
1154	899·445	13·933	4	3	− 18·	+ 1·8
1155	899·458	13·946	3	2	− 30·	− 10·0
1157	2,417, 903·529	0·905	3	3	− 33·	+ 3·9

TABLE II. *(Continued).*

Measures of *θ Aquilæ*.

Plate No.	Julian Date	Phase	No. of Lines	Weight	Residual	Velocity
	1908					
1533	2,418, 077·871	4·126	5	3	− 50·	− 3·0
1544	080·873	7·128	2	2	− 37·	+ 3·0
1556	096 857	6·000	3	3	− 48·	− 5·0
1583	098·821	7·984	5	3	− 31·	+ 7·0
1604	105·814	14·943	7	3	− 11·	− 5·0
1605	105·843	15·000	6	3	− 15·	− 10·0
1626	115·774	7·805	7	4	− 29·	+ 9·3
1634	117·824	9·855	7	5	− 29·	+ 7·5
1643	119·821	11·852	6	5	− 30·	+ 3·0
1651	120·781	12·812	9	5	− 32·	− 4·0
1659	126·729	1·648	2	2	− 36·	− 0·5
1679	131·785	6·704	5	3	− 39·	+ 2·0
1691	133·812	8·731	5	3	− 41·	− 4·0
1696	134·799	9 718	5	4	− 34·	+ 2·5
1704	136·818	11·737	6	2	− 33·	± 0·
1708	137·764	12·683	5	4	− 26·	+ 3·3
1716	138·809	13·728	7	5	− 19·	+ 2·5
1727	148·687	6·494	5	5	− 37·	+ 4·6
1730	149·735	7·542	5	4	− 39·	± 0·
1731	149·755	7·562	5	3	− 41·	− 2·2
1732	150·760	8·597	5	3	− 33·	+ 4·3
1733	150·840	8·617	2	2	− 41·	− 3·8
1735	151·743	9·551	6	3	− 43·	− 6·5
1736	151·756	9·564	2	1	− 30·	+ 6·5
1747	153·740	11·547	5	3	− 31·	+ 3·0
1755	154·744	12·551	5	2	− 31·	− 1·0
1756	154·764	12·571	5	3	− 26·	+ 4·0
1762	159·619	0·316	7	3	+ 35·	+ 10 0
1766	159·687	0·384	4	3	+ 33·	+ 13·0
1767	159·722	0·419	5	3	+ 16·	+ 3·0
1769	159·784	0·481	3	2	± 0·	− 8·0
1776	161·708	2·395	4	2	− 41·	+ 1·5
1777	161·740	2·443	7	4	− 39·	+ 4·0
1789	171·763	12·458	5	3	− 21·	+ 9·0
1794	173·697	14·392	5	3	− 24·	− 10·0
1799	173·635	15·328	8	2	± 0·	− 1·0
1800	174·658	15·351	6	2	− 2·	− 3·0
1801	174·695	15·398	6	3	+ 7·	+ 4·5
1807	175·581	16·273	6	2	+ 29·	+ 1·0
1808	175·605	16·297	7	2	+ 26·	− 3·0
1810	175·645	16·337	5	2	+ 22·	− 10·0
1811	176·645	0·228	5	3	+ 35·	+ 4·0
1812	176·664	0·247	5	1	+ 39·	+ 10·0
1813	176·681	0·264	7	2	+ 35·	+ 6·0
1814	177·659	1·242	6	4	− 30·	− 1·5
1815	177·680	1·263	8	4	− 33·	− 4·9
1822	178·702	2·285	7	5	− 35·	+ 7·0
1835	181·584	5·165	5	4	− 49·	− 3·0
1864	188·678	12·259	8	5	− 33·	− 1·7
1875	193·529	0·000	5	4	+ 51·	− 2·0
1876	193·570	0·040	5	4	+ 51·	+ 1·0
1878	2,418, 196·625	3·094	5	4	− 48·	− 2·0

TABLE III.
Normal Places

Mean Phase	Mean Velocity	Weight	Mean Phase	Mean Velocity	Weight
1·09	− 22·3	3	5·49	− 31·3	2
2·13	− 11·7	1	6·47	− 38·2	3
2·66	+ 0·7	3	7·96	− 48·9	2
3·09	+ 13·3	1	9·46	− 44·5	1
3·42	+ 24·9	2	10·73	− 40·5	2
3·72	+ 34·3	3	12·05	− 36·4	2
4·31	+ 51·0	1	13·93	− 37·4	5
4·54	+ 33·6	1	16·28	− 33·0	2
4·72	+ 22·5	3	17·05	− 26·7	2

With these elements it was decided to make a least-square solution for the normal places. Using the differential equation of Lehmann-Filhés* eighteen observation equations were formed, connecting the six unknowns with the residuals between the observed and computed values of the velocity.

Corrections to the first approximations were obtained as follows:

$$\delta\gamma = -0{\cdot}6 \text{ km.} \qquad \delta e = +{\cdot}011$$
$$\delta K = +2{\cdot}1 \text{ km.} \qquad \delta T = +{\cdot}134^{d}$$
$$\delta P = -{\cdot}004^{d} \qquad \delta\omega = 5°{\cdot}27$$

The resulting elements with their probable errors, as determined at a later stage are:

P = 17·116 days	± ·008 days	Final Elements (simple solution)
e = 0·691	± ·017	
ω' = 25°·27	± ·2°·1	
T = J. D. 2,417,731·434	± ·100 days	
K = 51·1 km.	± ·3·20	
γ = − 25·9 km.	± 0·64	
A = 83·0 km.		
B = 19·2 km.		

The residuals from the curve using these corrected values of the elements seemed themselves to lie on a curve, which repeated itself approximately twice during the period of the principal star and having an amplitude of about 8 km. The way the residuals from the observed velocities grouped themselves was not mere chance, there was no doubt that there was some secondary disturbance. The assumption was therefore made that

* *Astronomische Nachrichten*, 3242.

there was a third body whose period was commensurable with the period of the principal star, it going through all its phases in half the time required for that of the principal star. The orbit of the third body was considered circular and the secondary curve taken to cross the primary from above at a time T', Julian Day 2,417,732·634. Taking K' as 4 km. and considering θ as the angle at any time from T' the extra terms in the differential equation are :

$$- \sin \theta . \delta K' + \frac{2\pi}{P'} K' \cos \theta . \delta T'.$$

Correcting now our values of the computed veloicity for each of the eighteen normal places by an amount representing that due to the third body we have a new set of eighteen observation equations connecting the eight unknowns.

The following corrections resulted :

$\delta\gamma$	= − 0·01 km.	δT	= + ·030^d
δK	= − 1·4	$\delta\omega$	= + 0°·12
δP	= − ·0017^d	$\delta K'$	= − 1·3 km.
δe	= + ·007	$\delta T'$	= + ·159^d

The resulting values of the elements with their probable errors as determined at a later stage are :

P	= 17·114 days ± ·008	First approximation (Solution with Secondary Oscillation)
e	= 0·698 ± 017	
ω	= 25°·39 ± 2°·45	
T	= J. D. 2,417,731·464 ± ·092	
K	= 49·7 km. ± 3·31	
γ	= − 25·91 km. ± 0·66	
T'	= J. D. 2,417,732·793 ± ·349	
K'	= 2·7 km. ± 1·02	
A	= 81·04 km.	
B	= 18·36 km.	

The size of the corrections in some elements and the fact that the residuals (computed − observed) as obtained direct were not in all cases in close agreement with those obtained from the differential equation, *i.e.*, by substituting the values of the corrections in the observation equations, made another solution necessary. The values of ω and γ were, however, considered established, as the corrections were very small and the remaining

six unknowns were, with the last elements as the basis, formed anew into eighteen observation equations.

The resulting corrections were :

$$\delta K = -0{\cdot}02 \text{ km.} \qquad \delta T = +0{\cdot}039^{d}$$
$$\delta P = -0{\cdot}0022^{d} \qquad \delta K'' = -0{\cdot}05 \text{ km.}$$
$$\delta e = +0{\cdot}0037 \qquad \delta T' = +0{\cdot}080^{d}$$

The corrected values of the elements with their probable errors as determined at this stage were :

P = 17·1121 days ± ·005 days	Second approximation (Solution with Secondary Oscillation)
e = 0·6943 ± ·013	
ω' = 25°·39	
T = J. D. 2,417,731·503 ± ·070	
K = 49·68 km. ± 2·28	
γ = - 25·91 km.	
T' = J. D. 2,417,732·873 ± ·416	
K'' = 2·65 km. ± 0·86	
A = 80·84 km.	
B = 18·52 km.	

This solution should have been sufficient, but when substituting directly in the observation equations and comparing the residuals with those obtained in the ordinary way, there was one fairly large difference 0·40 km., two were 0·30 km. and the rest varied between 0·0 and 0·2 km. Furthermore, the probable errors of some of the quantities, particularly K, seemed too large. It was decided then to compute the probable errors corresponding to the previous corrections made. They are collected in the accompanying Table IV.

TABLE IV.

Summary of Corrections.

Elements	Preliminary Values	First Corrected Values	Second Corrected Values	Third Corrected Values
P	17·120	17·116 ± ·008	17·114 ± ·008	17·112 ± ·005
e	0·680	0·691 ± 017	0·698 ± ·017	0·6943 ± ·013
ω	20°	25°·27 ± 2°·1	25°·39 ± 2°·45	
T	J. D. 2,417,731·30	731·454 ± ·100	731·464 ± ·092	731·503 ± ·070
K	49·0 km.	51·1 km. ± 3·20	49·7 km. ± 3·31	49·68 km. ± 2.28
γ	- 25·3 km.	-25·9 km. ± 0·64	-25·91 km. ± 0·66	
		Assumed		
T''		(2,417,732·634)	732·793 ± ·343	732·87 ± 3 ·416
K''		(4·0 km.)	2·7 km. ± 1·02 km.	2·65 km. ± 0·86 km.
Σpvv	485· km.	292 km.	254 km.	235. km.

The values for P, γ, T' and K' were now considered determined. The probable errors, especially those in K', did not seem to be as low as they should be. As the probable error in ω in the later determination was larger than in the preceding one it was thought advisable to take e, ω, T and K' and see if by another solution lower probable errors and a better agreement between the ephemeris and equation would be obtained. As a result the following corrections were obtained:

$$\begin{aligned} \delta K' &= + 0{\cdot}29 \text{ km.} \\ \delta e &= + 0{\cdot}0009 \\ \delta\omega' &= + 0{\cdot}1743^\circ \\ \delta T &= + 0{\cdot}0013 \text{ days.} \end{aligned}$$

The final elements, taking into account a secondary oscillation, are then as follows. The Allegheny results, as discussed later, are given here for purposes of comparison.

Elements	Ottawa	Allegheny	
P	17·112d ± ·005	17·117h ± ·0042	Final Elements (Solution with Secondary Oscillation
e	0·695 ± ·010	0·685 ± ·011	
ω	25°·57 ± 1°·54	17°·53 + 1°·58	
T	J. D. 2,417, 731·504 ± 024	1907 Aug. 28, 697 ± ·034 days	
K'	49·97 km. ± 1·35 km.	44·69 km. ± 1·15 km.	
γ	− 25·91 km. ± 0·66	− 30·10 km.	
I	81·31 km.	73·88 km.	
B	18·63 km.	15·50 km.	
$a \sin i$	8,452,100 km.	7,665,000 km.	
P'	8·556 days	8·558 days	
T''	J. D. 2,417, 732·873 ± ·416	1907, Sept. 9·176 ± ·368 days	
	Time when secondary crosses primary from above		
K''	2·65 km. ± 0·86	2·39 km. ± 0·77 km.	
$a' \sin i'$	311, 800 km.	281,000 km.	

What seems peculiar is that the least-square solution diminished the period in each case, although from a comparison of the 1907 and 1908 observations when plotted the period would seem to be fixed about 17·120 days. The successive approximations in each case decreased the sum of the squares of the residuals as seen from Table IV. The final approximation gave $\Sigma pvv = 238{\cdot}3$ km. practically the same as the previous one. The agreement, however, between the equation and ephemeris is much improved, the greatest difference being 0·27 km.; the average 0·15 km.

and the probable errors are much lower. Table V. contains the phases for the normal places, reckoned from periastron with the period finally adopted, 17·112 days; the corresponding velocity with its weight and the residuals as computed directly.

TABLE V.

Normal Places

No.	Mean Phase From T	Mean Velocity	Weight	Residuals C − O
1	13·810	− 22·33	3	+ 1·85
2	14·871	− 11·75	1	+ 4·21
3	15·378	+ 0·66	3	+ 0·85
4	15·740	+ 13·33	1	− 3·21
5	16·143	+ 24·87	2	− 1·55
6	16·385	+ 34·34	3	− 0·44
7	0·019	+ 51·00	1	+ 0·38
8	0·166	+ 33·60	1	+ 4·75
9	0·346	+ 22·48	3	− 3·03
10	1·102	− 31·31	2	+ 5·95
11	2·107	− 38·20	3	− 3·16
12	3·533	− 48·93	2	+ 1·93
13	5·070	− 44·50	1	− 1·17
14	6·357	− 40 50	2	− 1·53
15	7·694	− 36·42	2	− 2·39
16	9·527	− 37·38	5	+ 0·36
17	11·932	− 33·00	2	+ 0·07
18	12·713	− 26·74	3	− 2·31

The curve representing the final elements is shown in Fig. 1, the dotted lines being the velocity-curves of the primary and secondary components and the heavy continuous line the resultant of these two. The final solution reduces the quantity Σpvv of the residuals for the normal places from 485 to 238·3. The least-square solutions, with the assumption of a secondary disturbance, seem, therefore, to have materially improved the values of the elements. The probable error of a normal place of weight unity as determined by $r = \pm 0.6745 \sqrt{\frac{\Sigma pvv}{n-\mu}}$, where n is the number of normal places and μ the number of unknowns is ± 2·75 km. The probable error of a plate, as derived from the residuals in last column, Table II., which are scaled directly from the curve, is for the 1907 observations ± 4·5 km. and for those of 1908 ± 3·5 km. Grouping the two years together the probable error of a plate is ± 4·0 km.

M. DESLANDRES' OBSERVATIONS.

It is rather hard to say how best to make use of these early observations. Though the measures are liable to accidental errors of considerable magnitude—one line only having been measured—they may, owing to the interval of some six years which has elapsed between the two series of observations, have

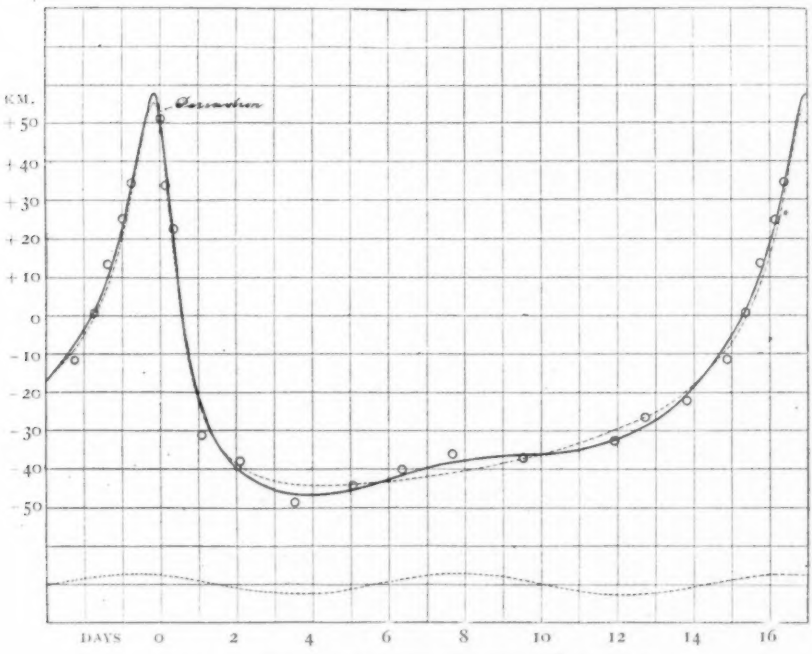

FIG. 1.—FINAL VELOCITY CURVE OF θ AQUILÆ

an important bearing on whether or not any changes in the elements have taken place during that time. Our 1908 observations seemed to be slightly greater positive than the velocities for 1907 for the corresponding phase. This may have been accidental, the difference being at most less than 2 km. If the absolute velocities of Deslandres' observations were known, it

would decide whether the velocity of the system has been changing or not during these six years.

If his two observations of the year 1901 are as they appear in his paper, we must conclude that the period has been changing during the interval. If we omit these two and use the remaining twenty-four of 1902 with our elements we get what appears on the face of it to be a much better agreement of the observations.

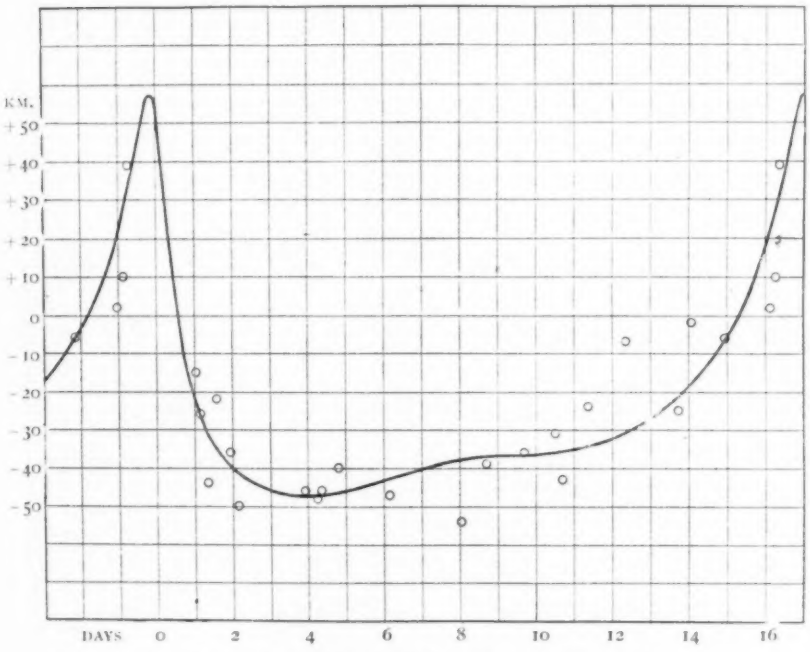

FIG. 2.—M. DESLANDRES' 1902 OBSERVATIONS

Fig. 2 shows these observations plotted according to our elements, 14 km. being added to each velocity. There is one discrepancy. The observations fall short of the curve by a common amount, 1·5 days. The number of periods elapsed between the two epochs is in round numbers 125. By increasing the period $\frac{1\cdot5}{125}$ or ·012 days this would be remedied, but while this value of 17·124 days

would not make much difference in Deslandres' observations, the least-square solution in our own shows it to be improbable. Here is a suggestion: Is it not probable that the presence of the third body will cause a rotation of the line of apsides similar to that caused by the Sun and Moon on the earth? A motion of the apse line in the direction of ω decreasing and at the uniform rate of $\frac{\cdot 012}{17 \cdot 112} \times 360^\circ$ or $0 \cdot 2524^\circ$ per period would account for this discrepancy. This motion, if it exists, would, in addition to decreasing ω and consequently the slope of the curve near periastron, also cause the maximum positive velocity to increase and the maximum negative velocity to decrease numerically.

These questions seem to call for further work on the star at some future time. I do not think the data is sufficient at present to make any definite assertion regarding any change in the elements themselves.

In conclusion I wish to acknowledge my indebtedness to the Chief Astronomer, Dr. W. F. King, for the advice he has given and the interest he has shown in the work.

Dominion Astronomical Observatory,
Ottawa, Canada,
December, 1908.

Additional Note on the Allegheny Determination of the Orbit

Since the foregoing was completed No. 7 of Vol. I., of the Publications of the Alleghany Observatory has come to hand containing the orbit of this same star as determined by Mr. Robert H. Baker. It is possibly the first case where two observers, working with different instruments and entirely independent of each other, have completed a discussion of an orbit at about the same time.

A comparison of the results is interesting. In some cases the agreement is remarkable, for instance the secondary oscillation; in other cases the agreement is not what might be expected. Speaking generally, I may say the reason for the differences exists in the observations themselves, the values Mr.

Baker has determined suiting his observations best, while the same may be said of our own. There is a gap in the Allegheny observations near periastron passage. The first normal place, phase $0^d \cdot 16$, depends upon two plates made the same night, the weights of the plates being about one-half the average weight assigned to a plate. The next normal place falls at phase $0^d \cdot 88$ and depends on two plates made on separate nights These have relatively low weights also. In this interval of 0·7 days ad-

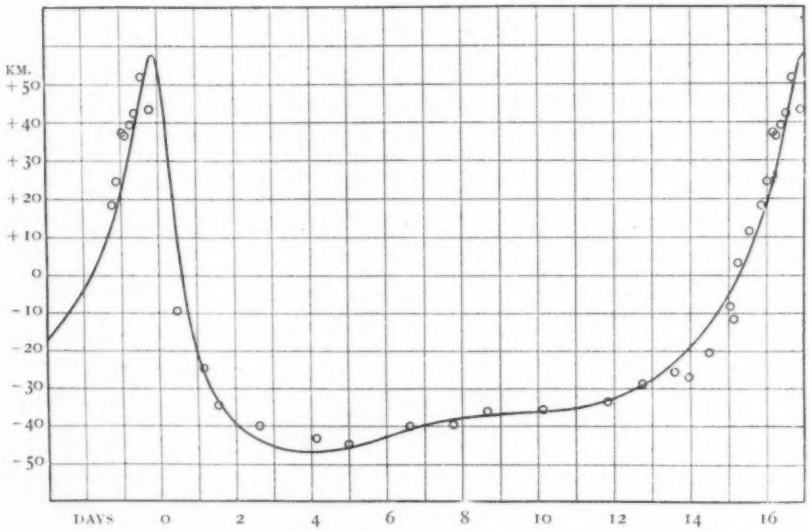

FIG. 3.—ALLEGHENY OBSERVATIONS: OTTAWA CURVE

ditional observations might, and I feel safe in saying, would tend to change the form of the curve. Our observations for phase $0^d \cdot 16$ depend upon one plate made in 1907 and three made in 1908, the plates being a little below the average weight. We have observations, however, for phase $0^d \cdot 34$ depending upon five plates made in 1907 and four made in 1908, the plates being all of average quality, and it is at this point that additional observations would be an advantage to the Allegheny data.

The systematic difference in velocities of 2 or 3 km. is partly accounted for by the different wave-lengths assumed. The probable error of an average plate here is ± 4·0 km., at Allegheny ± 3·3 km. The Seed 23 plates used at Allegheny have an advantage over those used here as, being of a finer grain, the spectrum lines would be easier to measure. Our greater number of observations around periastron ought to have much weight, however, in the consideration of the differences between the two results.

The Allegheny observations, with a correction for T to bring the times of periastron passage into coincidence, and the addition of 3 km. to each velocity, being a systematic difference, are plotted in Fig. 3, the curve shown representing the elements as determined here. A glance suffices to show that such a curve does not suit the observations as well as their own curve, and it would seem, therefore, that some further work on the subject would be necessary to explain the discrepancies.

January, 1909.

THE ECLIPSES OF LARISSA AND THALES

By Samuel Jennings

THE announcement of a new discovery which seems to threaten long cherished conceptions of the laws of nature (radium, for example) has always been received at first with scepticism, if not even with derision, until the reliability of the statement of fact becomes recognized, and the necessary modification of our ideas regarding natural laws receives scientific acceptance.

The same may be expected with respect to the discovery of a new fact affecting our established beliefs in ancient history. The all-important point is the reliability of the alleged new fact, which, primarily, rests upon the status and ability of the discoverer.

We are naturally reluctant to abandon long accepted tradition until forced to yield in the face of scientific truth which cannot be controverted. The new disclosure will be sure to meet with resistance from historians who can scarcely be expected to rate the practical certainty of complicated astronomical mathematics at its proper value.

Mr. Monck's criticism of my paper on ancient eclipses at page 299 of the *Journal of the Royal Astronomical Society of Canada* is a case in point, but it seems strange that an astronomer should prefer to rely upon ancient tradition rather than upon ascertained fact.

There are some, doubtless, who would rather believe that some mistake had been made as to the detection of a trifling error in the tables at present in use; or who would fail to realize that so small an error as scarcely to affect the purposes for which such tables are ordinarily used becomes a serious factor when brought to bear upon long periods of two or three thousand years.

It is no longer difficult to account for the circumstance that former astronomers, however accomplished, did not succeed in bringing the ancient records of eclipses into line, and hence pronounced them historically unreliable.

But it is just this that Mr. Cowell has succeeded in doing, and the proof of the fact consists in his having found that the same formula has verified each separate record, as I point out in my paper,—"This consistency is the essence of the proof." Mr. Monck ignores all this. He bases his criticism entirely upon ancient tradition as recorded by Herodotus, and not, as I do my hypothesis, upon ascertained scientific fact.

The recognized dates and respective zones of totality of the recorded eclipses, now harmonized, sufficiently warrant any hypothesis which is based thereon, however the deductions drawn from them may be open to criticism.

Under the evidence of such testimony, Mr. Monck's contentions are quite put out of court, even were there no other confirmatory evidence forthcoming, which I think there is, amply sufficient to convince any unbiased jury.

The defence of my deductions from these ascertained facts rests upon very similar grounds to that of the facts themselves. Mr. Cowell has succeeded in bringing harmony, astronomically considered, as touching the particulars of these anciently recorded eclipses, out of their former confusion.

Bringing his verified dates and localities of vision to bear upon these records, I think that my deductions suggest a similar harmony in the various narratives when read in the new light, and adjusted accordingly.

The eclipses of Larissa and Thales are, at last, definitely and astronomically determined. The precise date of the capture and destruction of Larissa is now known, viz.: 18th May, B.C. 603, supported by the results of modern exploration which prove that the inhabitants of that city were Assyrians, and not Medes, as Xenophon supposed, and that the place had never again been inhabited since prior to B.C. 600.

The precise date of the treaty ending the first Lydian war is now known to have been shortly after 28th May, B.C. 575. This, also, receives indirect confirmation from Scripture in support of the statement of Herodotus that Nebuchadnezzar (Labynetus) and Syennesis, the Cilician, arranged the treaty. In that year (B.C. 585) Jerusalem fell to the Babylonian army, and the captive king, Zedekiah, the high priest, Seraiah, and other nobles were taken to Nebuchadnezzar that he might himself pronounce sentence upon them. Where were they taken? To Riblah, a place situated about half-way between Jerusalem and Cilicia, and upon the road from Lydia to Babylon. Astronomy assures us as to the date, Herodotus states what was Nebuchadnezzar's business in that neighborhood in that particular year, and Scripture affords us incidental evidence in confirmation, as to time, place, and about one of the principal personages concerned.

But there is still further evidence which an astronomer will appreciate. Mr. Monck says: "It would be strange indeed if two contests, in both of which the Medes were one of the parties engaged, were terminated by different solar eclipses within the short space of eighteen years."

Examine the respective narratives and observe how very widely different were the circumstances recorded to have happened in connexion with each eclipse. At Larissa the assailants took advantage of a temporary scare, consequent upon the darkness of the eclipse, to secure entrance within the defences of the city. Xenophon's surmise that it was caused by "a cloud" sufficiently indicates a temporary darkness. That eclipse actually occurred about midday, after which, of course, normal daylight returned.

Now compare the description of Herodotus as to the eclipse of Thales. He says,—"night succeeding day" and again "day was suddenly turned into night." This was no temporary darkness, the combatants were not relieved of their consternation until daybreak the following morning, when, once again, they saw the light of the Sun. Mr. Cowell tells us that the Sun set

on the evening of that day, totally eclipsed, about east longitude 29°, that is in the very heart of the Lydian Empire,—a remarkable astronomical confirmation of Herodotus' narrative. Night had thus been anticipated by some hours.

Is there any getting away from these specific points related respectively by Xenophon and Herodotus, confirmed, as they are, by scientific determinations?

It seems almost superfluous to turn the search-light on the other side of the picture.

Mr. Monck says,—"as the eclipse of Thales took place within the life-time of Cyaxares, it must (according to Herodotus) have taken place before B.C. 592." Again, "the marriage (of Astyages) to the Lydian princess took place nearly sixty years before the fall of Babylon." Did it? How comes it, then, that astronomy cannot find any total solar eclipse, such as Herodotus describes, anywhere near that date (B.C. 592)? That of B.C. 603 was too far away to the east to have created so deep an impression in Lydia. The supposed length of the Scythian supremacy as well as the reign of Astyages, as recorded by Herodotus, is easily explained by his obvious mistake in confusing the eclipse of B.C. 585 with that of B.C. 610, which latter could scarcely have been visible in the south of Asia Minor, as it was total in the Scythian regions 250 miles distant, and its tradition was probably derived through Scythian channels. The precision of modern astronomical research shows that Herodotus interposed some twenty-five non-existent years, and fitted them into his history. The correction we are now justified in making brings the life of Cyaxares down to B.C. 585, and the Lydian marriage to that, or the following year.

The reliability of the periods of time recorded by Herodotus has often been questioned. They are certainly artificial and frequently exaggerated, and are quite an unsafe foundation upon which to base a historical argument, particularly when the testimony of astronomy is fairly considered.

My suggested adjustment, on the other hand, is based upon astronomical facts which we have upon recognized authority. When our chronology is corrected accordingly, it receives support from the circumstance that we find previously conflicting narratives fall harmoniously into line, and a flood of new light illuminates the isolated and fragmentary Scripture records of the same period, with which I have fully dealt in my recently published book—*The Story of the Captivity retold in the light of Recent Discoveries.*

BIRMINGHAM, February 12, 1909.

VOLCANIC PHENOMENA CONSIDERED IN RELATION TO PARALLELS OF LATITUDE AND MERIDIANS OF LONGITUDE

By T. E. Espin

"THIS general parallelism of the lines of external eruption with those of maximum upheaval, and their proximity to areas of pronounced depression cannot be looked upon as fortuitous," says Scrope in his classical work on volcanoes, and researches of later years have not given us grounds for modifying this statement. It seems quite clear that wherever a mountain range is uplifted, along the sides of it will be found volcanic outbursts. The two are inseparably connected. A careful study, therefore, of the lines the mountains take will give us also the lines of volcanic action. Now as far as I am aware the importance of the direction of these lines has not so far been realized. They will be found roughly to fall into two classes, lines ranging themselves on a parallel of latitude such as the Alps, the Pyrenees; and lines ranging themselves on a meridian of longitude, such as the Andes, etc. Moreover, in most of the volcanic regions a little investigation will show that these facts hold good. A careful study of Scrope's map of the Auvergne, given in his *Volcanoes of Central France*, makes it quite clear that the points of eruption through the great granitic plateau, are eruptions in the meridian. No one can view these cinder cones from near Clermont Ferrand, or from some favorable height on the plateau, without being struck with this fact. Quite apart from the map it is obvious to the eye. Again, in the north portion of Sardinia there is a similar line of eruption. And indeed in a very large number of volcanic groups the lines of eruption will be found to follow the same law. In some cases in the same volcanic region we have craters of both classes. A very good instance is that of the Alban Mountain. An ascent to the site of ancient Tusculum brings one to the lip

of the outer crater some eight miles in diameter, the axis of which it is not easy to determine, but probably it is a latitude crater. Inside this is a second crater which is one of longitude, the major axis being 1¾ miles, and the minor 1¼. An ascent of the highest point (Monte Carvo) affords a beautiful view of this crater, inside this again is a hill which was probably an irruptive vent. The crater is broken down on the west side. A vast stream of lava has flowed from here in the direction of Rome and at its highest point is Rocca di Papa. On the walls of the exterior crater two other craters have formed. One is now the Lago di Albano, the south-west side of which probably marks the exterior crater wall. The other is the Lago di Nemi, the more interesting of the two. This is a lake surrounded with basaltic walls some 300 feet high. The view of this crater from the Palazzo Cesarini is truly wonderful. Nemi appears to be a true basaltic pit crater, and a steep descent furnishes one with plentiful samples of basaltic bombs. Looking upwards from the water's edge at the sheer cliff of basalt cut as if with a knife on either hand, is a most impressive sight. Between Albano and Nemi and further south is the large crater of Arricia. This and Nemi are both longitude craters, while in Albano the angle of the major axis is about 45°. The following relations of the craters should be noted. The major axis of Arricia prolonged falls upon that of Albano. In the same way that of Albano falls upon Nemi. That of Nemi falls upon the break in the walls of the great central crater. We have, then, in these groups the original crater as a latitude crater, three longitude craters—Monte Carvo, Nemi and Arricia, while Albano lies at an angle of 45°. A study of the Neapolitan volcanic region affords equally striking results. Vesuvius is a longitude crater, and also Epomeo in Ischia, but, as Judd mentions in his *Volcanoes* (page 197), in the Phlegraean fields the volcanic vents appear to be formed along lines which assume a parallel arrangement. When one is on the spot the general east and west arrangement is fairly obvious, even more so than from the maps published by the Italian Government. The very numerous explosive eruptions have

caused a great deal of interference, but if we take the largest crater and the most perfect one, Astroni, the major axis prolonged falls upon Vesuvius, and the general parallelism of the vents clearly shows that these are all latitude craters. The vent of Vesuvius has itself shifted apparently on its meridian, and is now slightly to the south of the original vent which formed Somma. The result is to give the well known aspect of Vesuvius encircled by Somma which is so very striking as seen from Sorrento.

A point which is worthy of notice is that in Italy the ages of the sites of eruption are those of decreasing latitude. A visit to Bolsena, which is not far from the most northern point of the newer volcanic formations, shows that vast denudation has taken place, and its huge size seems to have puzzled Scrope, who says: "The Lake of Bolsena is so large, measuring twelve miles in diameter, that it is with some hesitation I venture to class it among the wide saucer-like craters of eruption." Near the town of Bolsena I noticed signs of subsidence, and conceived the idea that the whole of the original volcano has fallen in, while the islands, as Judd remarks, are evidently partly submerged tuff cones. The contrast with the Alban Mountain is very striking. These are evidently of much later formation. The chief sign of decay in the disappearance of the outer and inner craters at the west side is probably due to the rupture of lakes. After the outer crater was formed there was probably a period of quiescence during which a lake formed. The subsequent eruption destroyed the west wall and formed the inner crater. The inner crater may have been similarly ruptured by the eruption that caused the hill near the centre. The washing away of the inner crater wall left the great lava stream standing out as a neck on which is now Rocca di Papa. Nevertheless it is possible that the destruction of both walls in the same direction, lying as it does on the major axis of the outer crater, may have been the result of a fissure formed along the major axis. The land on the west side, however, gives one the impression of having been smoothed down by some enormous flood of water.

The third region—that of Naples, is the one in present activity. Here we have Vesuvius and Epomeo (active in historic times) and the Solfatara and Monte Nuovo, the first two being longitude volcanoes, and the last two latitude volcanoes. The most perfect example of volcanic forces arranging themselves on meridians of longitude, or parallels of latitude is, however, found in Iceland. Lock's *Askja, Iceland's Largest Volcano* is prefaced with a large-scale map, and also a list of all the eruptions that have taken place in historic times. From this map I have read off the latitudes and longitudes of the vents, and drawn up the following table :—

CLASS I. LONGITUDE (MEAN 16° 47′).

Name	Longitude	Latitude	R. Long.	D. Lat.	Eruptions
	° ′	° ′	° ′	° ′	
Lelrhnukr	16 54	65 49	+ 0·7	+ 1 45	4
Krafla	16 50	65 44	+ 0·3	+ 1 40	1
Hrossadalr	16 53	65 43	+ 0·6	+ 1 39	1
Bjarnarflag	16 47	65 36	0·0	+ 1 32	2
Askja	16 42	65 4	− 0·5	+ 1 0	1?
Knerkfjöll	16 40	64 38	− 0·7	+ 0 28	3
Oraefa Jökull	16 42	64 4	− 0·5	0 0	4

In this table column 4 gives the difference from the mean longitude while column 5 gives the increase of latitude.

CLASS II. LATITUDE (MEAN 63° 57′)

Name	Longitude	Latitude	D. Long.	R. Lat.	Eruptions
	° ′	° ′	° ′	° ′	
Oraefa Jökull	16 42	64 4	0 0	− 0 7	4
Skeidarar Jökull	17 12	64 4	+ 0 30	− 0 7	5
Grimsvötn	17 20	64 9	+ 0 38	− 0 12	3
Skaptar	18 7	64 9	+ 1 25	− 0 12	2
Varmardalr	18 40	63 56	+ 1 48	+ 0 1	2
Kotlurga	18 52	63 41	+ 2 10	+ 0 16	13
Eyjafjalla	19 26	63 39	+ 2 44	+ 0 18	2
Hekla	19 39	63 58	+ 2 57	− 0 1	20?
Raudukambar	19 48	64 12	+ 3 6	− 0 15	1
Trolladyngja	22 4	63 57	+ 5 22	− 0 0	5
Eldey	22 50	63 43	+ 6 8	− 0 14	10

In this table column 4 gives the increase in longitude and column 5 the difference from the mean latitude. These tables may be condensed as follows :

Class I. Latitude Extension 1° 45′, Eruptions 16
" II. Longitude Extension (cos lat.) 2 45, " 67

From these tables I have excluded Eldborg long. 22°·15′, lat. 64° 46′, the earliest recorded crater in eruption (990 A.D.) This evidently is the last of a more northerly line of vents which may be traced in the map as running parallel with those of Class II.

When we come to examine the groups of volcanic islands the results are no less remarkable. In Class I. I can only find two groups as follows :—

	Extent of Latitude	Longitude (cos lat.)	$\frac{l}{L}$
Ladrones	6° 50′	2° 43′	0·40
Antilles	7 26	0 28	0·06.

The fourth column is obtained by dividing the longitude × cos latitude, by the latitude. The British Isles may possibly be taken as another example since, as Geikie points out (*Ancient Volcanoes of Great Britain*, Vol. II., p. 466), "The Volcanic rocks are ranged along the greatest length of the group of islands in a general N. and S. line from the south of Devonshire to the far Shetlands. It is on the western side of the country they occur." Extending this line to the Faroe Islands gives a somewhat precarious result for column three of 0·29.

But for the second class we have far more material :—

CLASS II.

Name	Extent of Longitude (cos lat.)	Latitude	$\frac{L}{l}$
	° ′	° ′	
Azores	4 46	2 10	0·24
Canary	5 14	1 48	0·34
Cape de Verde N.	2 34	1 15	0·49
" " S.	1 34	0 22	0·23
Sandwich	5 5	2 28	0·48
Lipari	1 27	0 31	0·35
Aleutian	14 42	3 52	0·26
Navigator	3 16	0 49	0·25

If the distribution was equal the value in column 4 would be unity. The mean is, however, 0·38. The Galapagos Islands belong apparently to Class II., but are peculiar in this, as in so many other respects, that they have the high value of 0·77. We must not omit in our investigation the Mexican volcanoes which, says Humboldt, "are situated on a transverse fissure running from sea to sea." As was shown by myself, these mountains are all situated between 18° 59′ and 19° 12′ of N. latitude. This line extends 18° in longitude, or if carried to the Revillagigedo Is., as suggested by Scrope, 25°. A similar line is found in Java, Sumbawa and Floris between lat. 6° 5′ S. and 9° 15′ S., extending from 12° to 13° in longitude. On the other hand, the volcanoes of the Andes and of Kamchatka gives lines of great length from north to south.

From the results of this investigation we are, I think, warranted in drawing the following conclusions :

(1) Volcanic foci tend to arrange themselves approximately on parallels of latitude, and to a less degree on meridians of longitude.

(2) There is a distinct tendency in volcanic vents to shift from a higher to a lower latitude.

(3) After making allowance for what may be local causes, there is a probability that the major axes of craters and their distribution in any volcanic region are the resultants of two rectangular forces.

(4) These conclusions suggest that the phenomena observed are possibly due to tidal action. It is with considerable reserve that I venture to put forward as an explanation the possibility of some areas below the earth's surface passing from the potentially to the actually liquid condition either by some external force, magnetic, electric, diminution of pressure or by an internal condition, viz., chemical action. If such a possibility be admitted then, such an area of molten matter would be subject to tides in proportion to its size and shape. Such tides would have their maximum effect at the side nearest the equator in the northern regions and, we should expect, in the southern. Vents, due to

rupture of the overlying strata, would then occur along the lines of greatest tidal action, while the same action of the liquid mass would tend to liquefy zone after zone in decreasing latitude. Where there were active vents the land would rise, but where the equatorial flow had passed the latitude of the place, the vents would become extinct and the land would subside. A line of weakness having now been set up the same phenomena would hereafter repeat themselves, the magma at the sides of the original area becoming liquid, a second series of eruptions would take place in the same regions as the former, and the sequence of volcanic rocks would be the same. Undoubtedly in the general dislocation of strata at any epoch in the earth's history (Permian, Triassic, etc.), the molten mass in its migration southwards would encounter water, thus producing great evolutions of steam and causing earthquakes and paroxymal eruptions.

In conclusion I may add that I have already in *Publications of the Wolsingham Observatory, 1902*, called attention to one possible factor in eruptions, viz., the Moon's greatest northern perigee with a period of 8·856 years. At the time that research was published I was unaware of the very elaborate investigations of M. Perrey of Dijon. Had he, for the general perigee, substituted the greatest northern perigee, he would have anticipated my results. In this present paper I trust to have offered a solution of yet another possible factor in volcanic eruptions, not unrelated to the first. Where the factors seem to be so numerous, it may be of assistance to be able to clear up one, even if a minor one.

Tow Law, Co. Durham, England.

COMMENT BY PROFESSOR COLEMAN

The paper on *Volcanic Phenomena in Relation to Latitude and Longitude* is an interesting one and calls attention really to a rather frequent arrangement of mountain chains in a north and south and east and west direction, since volcanoes generally follow the lines of weakness in the earth's crust due to changes of level and mountain building. However, the paper appears to

leave out of account a striking feature of many volcanic chains, viz., their arrangement in wide sweeping curves. This may be seen in the Windward Isles in the West Indies, in the Aleutian and Kurile Islands in the North Pacific, and in the row of extinct volcanoes in the Pacific States. The paper overlooks, also, the rather frequent rows of volcanoes running diagonally to meridians and parallels, as in Central America. It seems to me safer to say that volcanoes exist in rows running in all directions, following fissures or lines of weakness of the earth's crust.

It seems very improbable, also, that there is an actual translation of molten materials beneath the earth's crust by tidal action.

A. P. Coleman.

UNIVERSITY OF TORONTO,
April 2, 1900.

THE CŒLOSTAT HOUSE OF THE DOMINION OBSERVATORY

By W. F. King

WITHIN the last few months there has been completed an addition to the Dominion Observatory for the purpose of carrying on investigations on the Sun, its nature and constitution, and for tracing, if possible, any relation between the changes observed on its surface and terrestrial climatic conditions. This addition comprises a shelter for a long-focus horizontal telescope, with a ventilated passage for the transmission of the light from the concave mirror of the telescope to the slit plate of a spectroscope located in the basement of the building proper.

The optical part of the equipment consists of a plane mirror 20 inches in diameter mounted with its axis parallel to the earth's axis and driven by clockwork at half the diurnal rate. The direction of the resultant reflected beam consequently remains constant. From this mirror the light is reflected upwards and to the south, where it is intercepted by a second 20-inch plane mirror mounted on a carriage which travels north and south along ways permitting adjustment for the varying declination of the Sun and consequent change in the inclination of the reflected beam. From the secondary mirror, the sun-light is reflected north to a concave mirror of 18 inches diameter and 80 feet focus, which also moves on ways to permit of adjustment to focus. From thence the beam proceeds to the focus, 80 feet south, being depressed downwards about 3½°, forming an image of the Sun about 9 inches in diameter in or just outside the basement of the Observatory. This image can be directed on the slit of a grating spectrograph of 23 feet focus, or can be moved to any other desired position to be photographed or otherwise investigated. The photograph shows the shelter for the cœlostat and secondary mirrors rolled back on wheels over the shelter for the

concave mirror, this being readily and easily accomplished by mechanism inside the house. This movable house, as well as the covered passage-way for the light beam, is constructed of wood covered with galvanized iron and is thoroughly and efficiently ventilated by louvres of galvanized iron as shown. This ventilation is essential for the production of a steady solar image, preventing stratification and non-homogeneity of the air through which the light passes. Between the passage-way and the wall of the Observatory the beam passes through a short tunnel with arched roof Although it would probably have been preferable to have continued the ventilated passage-way the whole distance, this was not feasible on account of the necessity for a drive-way beside the building. So far as can be seen the definition of the solar image has not thereby been affected, the telescope giving excellent definition, much better than had been looked for.

The cœlostat to the right and the carriage for the secondary mirror to the left are shown in the figure, the concave mirror being still further to the right. The slit of the spectrograph, whose optical axis produced would pass through the centre of the concave mirror, is in the tunnel about 5 feet outside the wall of the building. The concave mirror has a range of movement of about 16 feet so that the image can be formed in any position from a point 10 feet outside the wall to well inside.

RECENT PROGRESS IN ASTRONOMY AND ALLIED SCIENCES*

(ABBREVIATED)

By Otto Klotz

IT is a pleasant task to visit the various fields of science—those fields on which the sun never sets, and in which one sees as in the tropics on the same stem, the flower and the fruit. One thing that strikes one is the intense earnestness of the workers, each one is thoroughly absorbed in his work, and almost oblivious to his surroundings.

We are dazed at the amount of work done, and would be astonished at the small return, did we not know that such is inherent in the cultivation of the scientific field. Yet there is this consolation that the scientific harvest is imperishable, and adds to the storehouse of human knowledge, making the world better, and placing at the disposal of mankind more and more the resources of Nature.

We shall take up our subject *seriatim*, beginning with the progress of astronomy. It may not be out of place to discuss briefly the functions of an astronomer. It is a popular conception that, beside the enjoyment of many entrancing spectacles of celestial beauty, the fortunate astronomer sits at his telescope and *discovers*—always he *discovers*, and consequently many, when they are told that "discoveries" are not made or rarely made at the Observatory, are inclined to consider that the Observatory has failed in its purpose. An astronomer without "discoveries" to his record is like an angler who casts all day and comes home without fish—obviously an idle and incompetent person. Again, it is considered that astronomy is a most transcendental science.

* Address delivered before the Royal Astronomical Society at Ottawa, February 11, 1909.

It deals with infinite distances, with numbers beyond all power of human intellect to appreciate, and therefore it is supposed, on the one hand, that it is a most elevating study, keeping the mind continually on the stretch of ecstasy, and, on the other hand, that it is utterly removed from all connection with practical, everyday, ordinary life. And yet a little reflection will tell us that the work of the astronomer pervades our most common everyday life. Take the matter of time, by which we regulate our work, our time of eating and sleeping, the departure and arrival of every train upon which the safety of travel so much depends, the time for all this emanates from the Observatory. Or, again, we embark in a steamer to cross the trackless waste of water quite unconcerned about the certainty of our arrival at the proper destination. Although it is the captain that brings us to port, it is the astronomer that gives him the data for the Sun and Moon and stars and planets that enable the navigator to sail the boundless deep. These instances of the practical application of star-gazing might be multiplied indefinitely.

Turning now to the actual work of the astronomer and of his achievements in recent years, we may quote a short paragraph from an address of Lord Kelvin, in which he said: "Accurate and minute measurement seems to the non-scientific imagination a less lofty and dignified work than the looking for something new. But nearly all the grandest discoveries of science have been the reward of accurate measurements and patient, and long-continued labor in the sifting of numerical results." This gives the key-note of recent progress,—greater accuracy, better instrumental equipment, greater minuteness in measurements, and more attention to apparent discordances.

The groundwork of all astronomy is the knowledge of the position and place of the heavenly bodies. These are given in the star-catalogues, which are by far the most valuable assets of astronomical research.

Now the position of a star is affected by its parallax, and this in turn is dependent upon the distance between the earth

and the Sun. Parallax is the apparent displacement a body suffers by change of place of the observer. The distance to the nearest star is so great compared with our 92½ millions of miles from the Sun that it was formerly quite beyond the limits of instrumental equipment to measure it. To-day with the highly refined instruments and methods, notably the heliometric and spectrographic, definite results are being attained for a comparatively few stars of the myriads that strew the sky, and mark a milestone in achievement of practical astronomy. Bold indeed was the undertaking, when man first undertook to measure the dimensions of the earth; but bolder was it when he projected his measuring rod to the Sun; but what shall we say when we find him rushing off, measuring rod in hand, at the rate of 186,000 miles a second, and after 4⅓ years reaches the nearest star, *α Centauri*, a bright star of the southern hemisphere. This tremendous distance, quite beyond our grasp when stated in miles, is expressed by saying that its parallax is 0″·76. Let me put this in another way. Suppose the circumference of this cent to represent the orbit of the earth around the Sun, which you know is 185,000,000 miles in diameter, then the nearest star, using the same scale, would be at the distance somewhat greater than from the House of Commons to the Observatory.

To indicate but slightly how complicated and difficult is the determination of parallax, it need be but mentioned that the earth—our point of observation—is moving at the rate of over one and a half million miles a day around the Sun, the Sun in turn with its family of planets is moving through space at great velocity; at the rate of 12 miles per second, then each star in turn has its own motion, some with tremendous velocity, as high as 80 miles per second as seen from the earth, so that the actual velocity must be still greater, perhaps very much greater, and in this grand swirl, apparently chaotic, the astronomer is patiently trying to sift out and arrange the various motions and displacements and assign to each the proper cause. As a worker in this field truly says, "in spite of all our refinements of the present

day we are but at the threshold of this the most difficult problem in practical astronomy."

One of the most beautiful methods for the determination of star motion in the line of sight is the application of the so-called Doppler principle, first applied by Sir William Huggins, and carried on so efficiently in our own Observatory. This depends upon the change of rate of impact of waves. We may illustrate it by the change of the rate of sound waves but it is equally applicable to light waves, and that is its application in the determination of the velocity of stars in the line of sight. There occurs a displacement of the spectra of the manifold light-waves, and our fundamental note is the velocity of light, 186,000 miles a second. When a star is approaching us the light-waves are crowded together, when receding they are drawn apart. The refinements of the method are such that velocities of stars are determined which are utterly beyond the powers of the telescope and micrometer to measure by their change of position.

There is no such thing as rest in the Universe, nor is there such a thing as chaos ; the latter is simply an acknowledgement of our ignorance. Chaos was the attitude of our knowledge with reference to the distribution and movement of the stars until recently. The stars appear to be scattered at haphazard and their motion similarly fortuitous. This appears now, however, not to be the case. Their motion appears to be in two majestic streams or drifts relative to the Sun and in nearly opposite directions, but with considerable difference in their velocities. As for the distribution or density of stars for a given volume of space it is found that for a distance of about 200 light-years—remember what an immense distance this represents, light travelling for 200 years at the rate of 186,000 miles a second—the density is pretty constant. Then it diminishes until at 2,500 light-years it is only one-fifth that of the preceding.

When dealing with such stupefying distances the thought naturally arises, are any rays extinguished in their long journey to us, are they absorbed in interstellar space, as fogs so often absorb the welcome and friendly rays from the lighthouse? That

many rays are stopped in their journey by dark bodies, dead suns that undoubtedly pervade space it is safe to assume, but whether the luminiferous ether absorbs, that is the question. Now, there is a delicate test by which we may shed some light on the question, and that is by visual and photographic observations. For seeing, the eye utilizes the longer wave-lengths of light, *i.e.*, those towards the red end of the spectrum, while for photographing, *i.e.*, to produce the chemical action on the silver plate of the camera, the shorter wave-lengths, those towards the violet end of the spectrum, are the most effective. It has been found that the magnitude of stars does not progress equally as determined visually and photographically, the latter falling behind. This is equivalent to saying that the short waves diminish more rapidly than the long waves. It is but a short time ago since we could not conceive of matter becoming wholly detached from a celestial body, that is, to overcome the force of gravity, except by an excess of centrifugal force. Now, however, it has become amply demonstrated that there is another force, although intensely feeble, yet may, when the particles acted upon are sufficiently minute, overcome gravity, that is, light pressure, and which is inherent in all luminous bodies. That the light pressure may come into play, that is, be effective, the particles must be of an order of magnitude of the shorter wave-lengths and less. From these considerations it seems reasonable to assume that space is permeated to a greater or less degree by these vanishingly small particles or electrons, and from their relative dimensions or magnitude they will intercept or stop more of the shorter than of the larger wave-lengths, that is, will diminish the photographic effect of the rays more than the visual effect. This leads, then, to the important conclusion that light is absorbed in interstellar space. It may be remarked, however, that stars utterly invisible to the eye may yet be photographed. This rests on the circumstance that continued looking does not increase the seeing power, while with the camera, if it is exposed sufficiently long, the rays will be able to decompose the silver on the plate and thus secure a record.

Sir William Herschel set out nearly a century ago to observe binary stars with the hope of finding parallax, in the belief that the smaller star of the two was farther away.

It is gratifying to be able to state that our own Observatory is probably doing more work with reference to spectroscopic binaries than any other observatory in the world. Quite recently in this line Mr. Plaskett made a notable achievement in the definite determination of the variable velocity of *β Orionis*, *i.e.*, in conclusively showing that it is a binary star. Vogel as long ago as 1890 had suspected such to be the case, but the later determinations of the Yerkes and Lick Observatories were unable to support Vogel, believing his conclusions unfounded. Mr. Plaskett has secured spectrograms with our 15-inch telescope that definitely and unmistakably disprove the results of those giant monocles of 36 inches and 40 inches respectively, and confirm Vogel. To deduce the variable velocity of a star is a complicated matter, for every motion of which the telescope partakes, while the rays of light are recording themselves on the sensitive plate, is manifested in the position of the spectrum. Amongst these motions we may enumerate : the diurnal motion of the earth, the orbital motion around the Sun, including the lunar perturbation, the motion of the Sun through space, the proper motion of the star in space, and, finally, the orbital motion of a star, in case it is a binary. Verily a maze to be disentangled.

The occasional flaring up of a new star to quickly die out, has as yet not been satisfactorily explained. A plausible theory has been advanced, and that is that two dark bodies have collided, have scraped each other, with the result that the impact has generated enormous heat, producing a third body—evanescent but of momentary brilliancy—the new star—while the two bodies with their scorched and glowing sides of contact appear as variable stars caused by their axial revolution, showing alternately the luminous or heated and dark sides.

The greatest legacy we can bestow on posterity is not the discovery of some new star or possibly another planet, but in

handing down a catalogue of the positions of the stars at the present time. Since the powerful engine of photography has been brought to the assistance of the astronomer a great stride has been made in increasing the number of catalogue stars, for the photographic eye imprisons hundreds of stars on its retina, while the human eye laboriously with telescope, micrometer and clock secures but a single one. The photographic plate, however, secures for us only the relative position of stars, and what we require is their absolute position, so that for each star plate we must know the definite position of serveral stars to which to refer the others, and this is the work that now so many observatories are engaged in.

In a short time, say a few years, when our meridian-circle is mounted and all its parts have been thoroughly studied, and its idiosyncracies observed and measured, this Observatory will enter the list of national observatories to furnish fundamental star places, the most important of astronomic work.

One of the principal elements entering into fundamental work is that of time, represented by the astronomical clock. The *desideratum* with such a clock is above all things that its rate be uniform. The greatest obstacle heretofore for attaining that end was the effects of temperature on the length of the pendulum. By the recent introduction of invar, the new alloy of steel and nickel, which has a very small coefficient of expansion, for the pendulum rod, together with a hermetically sealed glass case for the clock, thereby eliminating the effect of change of atmospheric pressure; and also the application of a thermostat by means of which the clock is kept at a constant temperature, Mr. R. M. Stewart gives to our Observatory a time service second to none, —neither the Greenwich, Berlin, Paris nor Washington national observatories excel ours in this respect. This conclusion is not a matter of opinion, but one simply supported by figures and records.

Let us dwell for a short time with that body, which, barring the earth itself, our domicile, is of the greatest importance and

concern to us, more than the rest of the universe put together—the Sun.

With the naked eye the surface of the Sun reveals to us nothing save at times spots whose existence has been known before the invention of the telescope. When the telescope was applied a better scrutiny of the spots could be made; their position and magnitude from day to day, from week to week and from year to year noted. As observations increased, their mystery to a large extent increased. However, in course of time certain facts were established, for instance, that the spots were confined within certain limits, that they waxed and waned, that they were not merely dark patches on the surface but had some depth, which was shown by their appearance near the edge of the Sun's limb; furthermore, that there was periodicity in their appearance, that is, there were periods when there were more spots than at other times. This period fluctuated slightly about 11 years. From numerous observations of spots and their reappearance, making due allowance for the position of the spot with reference to the Sun's equator, as the spots have a differential motion, the time of rotation of the Sun, about 25 days, was determined. What has been said is the result of direct visual observations of the Sun. The changes that were observed and the activity manifested on the surface of the Sun served as a basis for hunting up synchronizing effects upon the earth. These have so far given only in one instance an indubitable counterpart, and that is the magnetic effect. During a period of maximum sun-spots we are certain of a maximum of magnetic storms, as shown by magnetic instruments.

When the chemist is given an unknown substance, he takes it to his laboratory, weighs it, determines its specific gravity, treats it with chemicals, and generally by a system of elimination first finds what it is not, and eventually what it is. The astronomer, however, in his search for the composition of the bodies of the universe is unable to bring directly the substance to his laboratory, he contents himself with questioning emissaries in the form of rays that come from the respective body, and these emis-

saries tell the story of their birth, their life-history as truthfully and well as if the substance itself had passed through the vicissitudes of the chemist's crucible. The astronomer's engine of is the spectrograph, the one designed especially for the Sun being called the spectro-heliograph. Every body or substance when heated to incandescence sends out certain definite and determinate radiations dependent upon the nature of the body. These radiations manifest themselves as waves of certain lengths, measured from crest to crest. The rate of propagation of these waves is the same for all, but the time of the to-and-fro excursion, constituting the wave-length, is influenced by the medium through which the waves pass, and this property enables us by means of prisms to spread it out, to disperse the various kinds of rays in a band and to permit their examination. When we have heated to incandescence known substances of the earth, and examined spectroscopically the light which they emit, we are in possession then of a scale of comparison with the light or radiations from luminous bodies outside of the earth. From the particular length of a wave we have learned to know what it means to us. Certain ones excite the cones and rods of the retina of the eye that gives us vision; others, again, are strong in their chemical action, while the longer ones give us the sensation of heat. It becomes evident, then, that a close examination, which is by no means a very simple matter, of the very large number of radiations from a glowing body tells us its physical constitution. It might be mentioned that in comparing the solar spectrum with that of known bodies of the earth, that the lines appearing bright for terrestrial incandescent matter such as sodium, or iron, or calcium, or magnesium, or hydrogen appear dark in the solar spectrum due to the absorption by the respective glowing vapor of these elements. That is, rays passing through an incandescent vapor absorbs exactly those particular rays which are characteristic of it in emission. Thus the Sun revealed that it is, broadly speaking, composed of the same matter as the earth, however in an incandescent state.

The mysteries of the Sun are far from unfolded. With in-

creased and more refined observation follows the train of necessary interpretations. It is one thing to establish a fact, but quite another to explain it by physical laws. And, furthermore, there is sometimes difficulty in establishing a phenomenon as a thing of objective existence. A case in point with the Sun, Professor Julius of Utrecht has concluded from recent experiments and investigations that the chromosphere and prominences, so well known for many years, do not exist as they appear to us; the bright lines of their spectra are not the radiations of luminous gases, but photospheric light brought into our line of vision after anomalous refraction through non-homogeneous gases. This is an illustration how tenacious Nature apparently is in giving up her secrets—the eternal truth—and how slow in reality the progress of science is; by this I mean the establishment of laws of nature—of truths—that will stand the test of time, as, for instance, Newton's Law of Gravitation.

In solar investigations a new competitor or co-worker has entered the field,—the Solar Research Observatory at Mount Wilson, under the directorship of Prof. George E. Hale. It is generously supported by the Carnegie Institution, and there is every reason to believe that most important results, not only of a high scientific value, but results of the most practical value, very likely in the domain of meteorology, will follow from investigations and observations at Mount Wilson. Our own Observatory will undoubtedly add its quota too in solar research.

Among the more important discoveries made by Hale and his co-workers in the study of sun-spots may be mentioned:

1. That the spots are cooler than the surrounding regions;
2. That they are centres of violent cyclones;
3. That they are accompanied by magnetic fields of great intensity.

With reference to the magnetic field of the sun-spots, it will be remembered that according to the electronic theory the electrons in their cyclonic motion of great velocity produce magnetic lines of force. Light passing through such a magnetic field produces the so-called Zeeman effect, whereby the lines of

the spectrum are subdivided. Now if the sun-spots are magnetic fields they must show this peculiarity with reference to the spectrum, and this has been found to be the case; and, furthermore, the change of field, as must occur by the revolution of the Sun together with the spots, should also show a corresponding change in the spectrum. Looking at the spot at the centre of the Sun, the light would come in a direction of the axis of the whirl, while when viewing the spot at the edge of the Sun, the direction would be at right angles to the former and therefore manifest itself accordingly on the spectrum, and this has been most recently confirmed. So that it has now, very recently been definitely determined that the spots are magnetic fields of great intensity.

The object in the heavens, although recognized by few outside of astronomers, that has aroused a lively interest amongst the people, is Mars. And the reason is not far to seek. The human mind likes to give rein to fancy; what is more delightful to the child than fairy tales, and with what avidity did the public drink the flood of semi-scientific tales of Jules Verne. Here we have a planet although smaller than the earth yet otherwise much resembling it. The first phenomenon discovered on it were the polar caps, similar to our alternating polar snow caps. This was enough to fire the imagination and people the ruddy planet with beings, and as we had never seen any beings other than ourselves, the Martians were made of our image, however, to conform to the conditions of their planet, which meant, as the force of gravity is only about a third what it is on the earth, that its inhabitants were probably giants, which seems somewhat paradoxical; however, theoretically it is sound that the smaller planets whose gravity is less than ours should have larger beings than we have, for the crushing strength of the bony frame supporting it is less. Such giants on that planet could work and do things in the way of lifting and jumping, that would make our sports and Caledonian games look cheap. When later Schiaparelli, Flammarion and Lowell covered the planet with canals, and the last insists on their construction by intelligent beings,

we feel a genuine satisfaction that we are not orphans in the universe, that there are fellow beings, perhaps armed with huge telescopes, scanning the face of the earth, watching our seasons which could be distinctly seen by our polar caps and by the appearance and disappearance of foliage and verdure causing a change in color. Our canals they would probably not see, certainly not the Georgian Bay Canal, but they could see enough to satisfy them that some puny things probably crawled about the earth. Mars surpasses us in satellites, for it has two. However, they are very small, and give but a very small fraction of the light of our Moon. The larger and inner one Phobos has the unique peculiarity of celestial bodies that it rotates about its parent body very much faster than Mars revolves on its axis, which is about a day. The consequence is that Phobos rises in the west and sets in the east about five and a half hours afterwards.

Jupiter's equatorial belts and great red spot still await a satisfactory explanation. Ever since Keeler showed spectroscopically that Saturn's rings were composed of discrete particles, interest has been manifested in the rings, and new divisions have been discovered in the groupings of these tiny wanderers. What a glorious sight a Saturnian night must present, innumerable moons spread like a band across the starry firmament. There would be no rising nor setting, and furthermore the rings would be invisible in the polar regions or on the equator, and between these limits would vary in apparent breadth and brightness. The constitution of the rings is of such flimsy material that the stability of these rings is not at all assured, owing to the perturbation of the ten satellites that accompany Saturn.

A word about comets, those will-o'-the-wisps, those tramps of the heavens, those fickle, fluffy, feathery fabrics that wander through space, permitting themselves to be influenced in their course by everybody coming within their reach. For them there is many a Scylla and Charybdis and the voice of the Siren seduces them. Mysterious beings they are; material spirits that whisper of the confines of the universe. By far the greater number are but transient guests, they come to warm themselves hurriedly at

our central orb, and then plunge again into the depths of cold, cheerless space.

Comets not so long ago were the bodings of evil, of war, of famine and death,—a gross injustice to these light-hearted, harmless airy-nothings that come on a friendly visit to delight us, and whose evolutions in their merry dance surprise and astound us. Would that they would favor us with more of the bright ones, such as many of you saw and recollect of October, 1882 ; and a few will perhaps recall the glorious sight of Donati's comet in 1858.

There is one old faithful visitor, however, in whom at present the astronomers are much interested. It is Halley's comet, and although it has not quite the regularity in its motion that the planets have, yet it has never failed to show its face, since the Christian era, and sign the attendance book, sometimes a little early, sometimes a little late. To few it is allotted to see this comet twice, for its period is a little more than years three-score and ten. It is due next year in April or May, and as a telescopic object the hunt for it will begin this year. Its interest lies more in the fact of its regular recurrence than as an object of particular celestial display. It passes around the Sun within our orbit, and then goes off beyond the orbit of Neptune, our outermost planet, before it starts on its return again.

Perhaps to us, as integers of the British Empire, the most interesting historical association of one of the appearances of this comet is the battle of Hastings in October, 1066, when William of Normandy, the Conqueror, defeated Harold. To this day there is preserved in the archives of Bayeux a tapestry woven, it is said, by William's wife, and in which the historical event of the conquest is associated with or heralded by the comet, which had appeared in the preceding April.

The motion of the comet around the Sun is opposite to that of the planets. At the present time (February) it is about midway between Betelgeuse, the northerly bright star in Orion, and Aldebaran the bright star in Taurus, which are well seen in the south. Its magnitude is probably 17, and it will be the end of

the year before it will become visible with a moderate sized telescope. An interesting phenomenon is looked forward to, and that is, that its conjunction will be very near the time of a total solar eclipse next year May, so that the beautiful spectacle will probably be presented in southern Tasmania, where the totality is visible, of seeing the corona and prominences, those brilliant flashes of light, together with the comet, enhanced in beauty by the obscuration of the Sun.

At the present moment there is a comet in the heavens that has aroused much interest. It was discovered by Morehouse of the Yerkes Observatory last September, and from the very beginning showed extraordinary activity in various ways. Shortly after its appearance it was found amongst our circumpolar stars, that is, it was nearer the pole than the Great Bear. Christmas Day it made its mad rush around the Sun, or passed its perihelion as it is technically termed, and now it is far down among the southern constellations, an object of scrutiny for the Cape and Australian observatories. It is a veritable spendthrift, scattering its substance to the winds so to speak, and changing its form almost as rapidly as the fleeting *aurora borealis*, to the amazement and consternation of astronomers. Such profligacy can only take place when the substance or matter composing the comet is in an extremely attenuated condition. Although the comets visible to us pass among the planets yet has no comet ever disturbed their orbit in the slightest. One writer expresses the mass of comets in a very graphic, although exaggerated way by saying "that a comet properly packed could be carried about in a hat box or a man's pocket."

Of the "Allied Sciences" referred to in the subject of my address I shall confine myself more particularly to those in which we are engaged at the Dominion Observatory—Geodesy—Gravity —Terrestrial Magnetism and Seismology. The subject of Physics, including Chemistry, will undoubtedly receive full treatment by Professor Barnes in his address before our Society next month.

The word discovery is scarcely applicable nowadays to geodesy; the progress of the science rests more on successive

refinements attained in the work, both in angular and linear measurements. The latter have always involved much labor and expense in the measurement of base-lines, the principal disturbing factor being the uncertainty of the expansion or contraction of the measuring apparatus. Now, however, since the recent invention of the alloy of steel and nickel, called invar, being the first two syllables of the word "invariable," whose coefficient of expansion is very small indeed, almost a negligible quantity, together with the iced-bar apparatus for standardizing an invar band or wire, makes the measurement of base-lines a comparatively simple and highly accurate operation.

The long-looked for and necessary geodetic survey of Canada has now been successfully inaugurated under the direction of Dr. King and is vigorously carried on by Mr. Bigger, so that the reproach long resting on Canada as being the only civilized country without a systematic geodetic survey is now removed.

I have just spoken of gravity. This is one of the constants intimately bound up with the earth, the constant of gravitation. Its value is pretty accurately known, and as it is connected mathematically with the figure of the earth, which too is pretty well known, it serves the purpose of finding out the distribution of matter on the earth's surface and crust. Until recently no means were available for carrying on observations at sea in order to determine the force of gravity there, as is readily done on land by pendulum observations. Now, however, such observations have been successfully carried out by comparing the pressure of the atmosphere as measured by a barometer and by the boiling point of water The results show that gravity at sea is in general normal, that is, dependent upon the latitude of the place of observation. The observations were made over the Atlantic, Indian and Pacific oceans, and are a distinct contribution to our knowledge of the earth.

There are several departments of physical investigation in which little progress has been made during the last fifty years in getting at the fundamentals underlying the elements involved. One of them is terrestrial magnetism.

In 1904 the Carnegie Institution at Washington undertook to attack the problem in a comprehensive manner, especially in supplying magnetic data for the accessible regions of the world not before occupied, and more particularly to make a systematic magnetic survey of the various oceans.

The Dominion Observatory, under the directorship of Dr. W. F. King, has recently inaugurated a systematic magnetic survey of Canada and the data obtained, especially the declination of the magnetic needle, or the variation of the compass as it is popularly called, will have much practical value, outside of its scientific interest.

The subject of Seismology, treated scientifically, is of very recent date. It is but a comparatively few years since the records of the occurrence of earthquakes were confined to the direct perception of the senses, *i.e.*, that the quake was felt or heard or seen, but now, with our highly sensitive instruments or seismographs as they are called, no violent or destructive earthquake can take place in the uttermost regions of the earth without being recorded on every instrument. This is undoubtedly a great achievement, for the actual movements that the earth particles undergo are extremely small. Take the Calabrian catastrophe, that cost a loss of 200,000 lives a few weeks ago, and untold millions in property, when the first waves arrived they imparted an oscillating movement to the earth particles here, giving them an orbital motion with a radius of one six-thousandth of an inch. Of the dependence that can be placed on the record made by the seismograph I may be permitted to refer to the report "that a terrible earthquake has devastated several towns and villages in Southeastern and Eastern Spain." These are the words in the despatch in our morning paper on January 30. That morning, after having had the sheet of the preceding day developed, I examined it carefully, and then reported to the Director that the despatch can not possibly be true, for such an earthquake could not take place without recording itself in a very decided manner here. When the evening papers were issued that same day they bore the head-lines "No serious earthquake

occurred in Spain," thereby confirming the Ottawa seismogram.

It is only now, as I have said in my address on earthquakes, that we are obtaining direct evidence of the nature of the constitution of matter beneath the surface of the earth, in short of the interior, and especially of the change in density and elasticity with the depth.

There is no study of more importance than that of the earth itself, and in that study the movements of the earth's crust forms a very important part. About this latter phase Dr. Jagger, himself an eminent geologist, recently published an article drawing attention not only to our ignorance but also to our hitherto indifference to the subject, and he illustrates it by some caustic and ironical paragraphs. He imagines an inhabitant from Mars to visit the earth, and after first paying a visit to the Lowell Observatory at Flagstaff, where his own existence has been so wonderfully interpreted, he suddenly appears amongst a group of geologists when the following dialogue occurs:—

"Where you know the heavens so well, of course your own earth is to you as an open book?"

"Yes," reluctantly.

"You have observatories for the recording of all earth phenomena?"

"No."

"What! Did you not learn everything about local terrestrial motions before you studied the stars?"

"No, we do not know anything about terrestrial movements."

"Do you mean to tell me that you have not many instruments for observing them?"

"We have the seismograph, but none of us understands it, and as for other earth motions, all we know we have learned from the physicist and the astronomer."

"But you live on the earth, and have to meet every crisis as it arises; can you foretell nothing?"

"Well, you see, we don't think of it that way. We treat it historically, and make notes and use a hammer and a compass, and are very much interested in the bones of Jurassic reptiles

and in making maps of the rocks, and in finding out all about iron and coal. But we have no such precise knowledge as the astronomer."

The above is not exaggerated. This may be added, however, that the solution of earth movements will most likely be made by the physicist and mathematician.

My story is now told. I have wandered over the fields of astronomy and some of the other sciences. I have picked some fruits here and there and served them to you fresh from the vines and branches. That they are good and appetizing I know, but I am not so confident that I have presented them in a manner that they were enjoyed, as they deserve to be.

MEETINGS OF THE SOCIETY

At Toronto

February 9.—Mr. A. Sinclair, Librarian, reported that 576 publications had been received during the year 1908.

The paper for the evening was on "Solar Activity During December, 1908," and was contributed by Prof. Luis G. León and Mrs. León, of Mexico. The authors of the paper had carefully watched the Sun's surface nearly every day during the month of December and sent numerous drawings of sun-spots and faculæ they had noted. More than one spot had been seen to develop and disappear at a considerable distance in from the limb. Considerable discussion followed the reading of the paper. (The paper is printed in the January–February number of this Journal).

February 23.—The meeting was held in the Physics Building of the University of Toronto. Prof. J. C. MacLennan gave a lecture on "Some recent verifications of the Atomic Theory of Matter." The lecturer traced the development of the atomic theory from its beginnings to the present time, giving particular attention to recent experimental work, pointing to the conclusion that matter is discontinuous. Special reference was made to Rutherford's work, whereby he was enabled to calculate the number of particles actually torn from the chemical atom during radio-active discharges. The method of doing this was explained by diagram and by experiment. Liquid air was poured from Dewar Thermos flasks and allowed to evaporate to illustrate the compressibility of the constituent particles. Perrin's colloidal particles were exhibited under the microscope in such a way that the particles in solution became visible by the specialized action of light.

A vote of thanks was moved by Mr. John A. Paterson and seconded by Dr. A. D. Watson.

March 9.—The following were elected members of the Society :—

Robert Hartley, 16 Adelaide Street, W., Toronto.

Charles P. Sparling, 530 Dovercourt Road, Toronto.

A short address was given by Mr. J. R. Collins on "Some Simple Problems of Vision, Curvature of the Sky, Horizon Level, etc.," and with the aid of blackboard diagrams some very interesting points were dealt with. It was stated that an object directly overhead, such as a point in cloud strata, makes an angle of 90° with the horizontal plane passing through the eye of the observer ; and that as the point, at the same elevation, is shifted from the perpendicular, the angle gradually closes up, becoming less and less until it finally disappears ; the line from the point to the eye being merged in the horizontal. This gives the curved appearance overhead, in every direction from horizon to horizon concaved, with the centre of curvature always perpendicular to the eye of each observer. The same applies to the perception of a surface underfoot, only the observer looks down instead of up, though in this case the concavity is not so generally marked on account of the observer's horizontal plane of vision being usually close to the observed surface. At great elevations the observer's horizontal plane of vision is at considerable perpendicular distance from the earth's surface, and the concave appearance becomes quite marked. The curvature of the earth's surface is so slight as not to materially modify this effect until a great perpendicular distance from the surface is reached, when the horizon drops below the level of the eye and the earth begins to recede from the observer as a spherical body. This opened the way for discussion on some of the points raised, the figure of the earth, refraction, etc., in which Messrs. Paterson, Sharpe, Miller, Musson and Elvins took part. A question asked by Mr. Elvins, as to the practical meaning of the mathematical term "fourth dimension of space" was answered by Professor De Lury.

March 23.—The following were elected members of the Society :—

Newton L. Forster, Trafalgar, Ont.

M. L. Atkinson, 50 Leopold St., Toronto.

Mr. L. H. Graham described an unusual observation of the setting Sun he had recently made, from Scarboro' Heights, when the Sun appeared a double object just above the western horizon, a phenomenon due no doubt to atmospheric refraction.

The paper for the evening was by Mr. R. F. Stupart, Director of the Meteorological Service of Canada, on "The Winds of the Globe." The lecturer gave a short résumé of the history of meteorological science and its development to the present time. It was explained how the various general air currents were located and mapped over a large portion of the globe, and it was shown how, by noting the direction of motion of the various air disturbances over large areas, the meteorologist is able to predict with some success the conditions of weather for 24 hours.

April 6.—The meeting was held in the Chemical Building of the University, the President in the chair.

Professor S. A. Mitchell, of Columbia University, New York, gave an account of the work in which he had taken part as a member of the United States Government Eclipse Expedition to Spain, 1905, and the work accomplished by the expedition. The lecturer also recounted his experiences in Sumatra, whither he had gone to observe the eclipse of 1901, as well as incidents at Manila, on the way. Professor Mitchell secured some admirable photographs of the "Flash" spectrum, which demonstrated its identity with the solar absorption spectrum. The lecture was illustrated with many fine slides from photographs taken by the lecturer, and incidentally the manners and customs of the two countries and their people were described entertainingly.

On account of wet weather, the audience was not large, but their appreciation of the address was evidenced by a vote of thanks moved by Dr. C. A. Chant and seconded by Mr. J. G. Boyce.

April 20.—Under the head of observations Mr. A. F. Miller reported an interesting observation recently made, at a time when the full moon and Jupiter were near one another in the heavens, in which the planet, with a magnifying power of 300, appeared larger than the disc of the full moon, the two objects being seen at the same time, one with each eye.

Reference was made by Mr. J. A. Paterson to the recent death of Mr. John Phillips, for many years an active member of the Society, and a contributor to its programmes, having reference especially to the problem of the genesis of the Moon. Mr. Paterson bore witness to his thirst for inquiry and knowledge and his love of the truth. The President and Secretary were deputed to send a message of sympathy from the Society to Mr. Phillips' family.

The paper was by Professor A. T. De Lury upon the subject of "Comets and the Computation af their Orbits." Professor De Lury explained the nature of comets, and their relation to the solar system, mentioning several of the most famous comets and their characteristics, in particular Biela's and Halley's. He described the form of orbit travelled, and how the orbit might be changed by the attraction of some great body on the comet. Finally he took up the method followed in computing a comet's orbit, and explained the difficulties met with and overcome. The lecture was followed with the closest interest, and at its close Mr. John A. Paterson, who was in the chair, expressed the high appreciation of the Society in having the extremely difficult subject so clearly treated.

The Rev. C. H. Shortt, a member of the Society, and recently of Japan, was present, and on being called upon, said a few words. He stated that the Japanese are now giving a good deal of attention to astronomical matters, as is evidenced by the publications of their observatories, and expressed his pleasure in meeting his old friends in the Society again.

E. A. D.

AT OTTAWA

February 11, 8 P.M.—Dr. Otto Klotz read a paper on "Recent Progress in Astronomy and Allied Sciences." The paper, slightly abridged, appears in this issue of the JOURNAL (page 117).

February 25, 3 A.M.—Mr. C. C. Smith, B.A., read a paper on "Astronomy as Applied to Surveying."

Mr. Smith first pointed out that since the introduction of telegraphy in longitude determinations and of Talcott's method in latitude observations all improvements in mathematical astronomy have consisted in perfecting the instrument or the methods. Instead of discussing these improvements he proposed to show briefly the debt which surveying owed to astronomy. The field of operations ranged from the simple one of finding azimuth by an observation of Polaris at elongation to that of finding the shape of the earth from observation residuals.

Surveying resolves itself into the problem of finding the co-ordinates of terrestrial points, whether the surveys be simple ones involving small distances, or whether they be for determining the positions of widely separated points on the earth's surface, and the directions and lengths of the lines joining them.

In the simpler surveys all points are referred to some initial point or origin, a horizontal reference plane, and a reference line. Such surveys are as old as civilization. Astronomy may be applied to furnish the reference line. The Egyptians have the honor of being the first to realize this, as is evidenced by the pyramids which are set square with the cardinal points. The astronomical reference line is the ideal one, being superior to the compass bearing or to a line joining two marked points. As the distances are short, errors of less than 30″ do not produce serious results. The observations for azimuth are very simple, and with a suitable instrument may be taken in the early part of the morning or in the latter part of the afternoon. In ordinary surveying the astronomical part of the work is by far the most accurate part. The astronomical bearing is of the utmost importance in descriptions and in resurveys. In spite of all this, however,

some surveyors still dislike the taking of astronomical observations.

In larger surveys, however, there are more difficulties and complications. The simple horizontal plane of reference must be discarded, and the same reference line can not be carried through the whole survey. Such surveys are useful for mapping large areas, for correcting smaller surveys and for acquiring a knowledge of the size and shape of the earth.

The history of the problem of determining the figure of the earth is to a great extent the history of mathematical astronomy, and though the problem itself has not been solved yet, many highly important discoveries have been made while attempting its solution. Gravity determinations and measurement of arcs combined with determinations for latitude and longitude are the principal methods employed. The surface of the earth is defined as the surface which the water in the sea assumes, and this surface is extended through the continents by defining it at any point as the level that the sea would take if extened through the continent in a canal. This surface is called a geoid. As this surface is an equipotential one, any internal changes in the distribution of matter will affect its shape; such changes would become apparent by changes in sea-level along coasts and changes in latitude of points.

Investigators employing deductive methods such as Newton, Huygens, Clairaut, MacLaurin, D'Alembert, Legendre and Laplace have given us the Law of Gravitation, the law of the change of gravity and the law of change of density of the earth's strata. Upon these theories and laws practical surveying and astronomy worked to prove or disprove, with the results that in the main the theories were upheld. Laplace also showed by theory that the depth of the sea was a small fraction of the compression at the poles; also that local disturbances do not distort the geoid to any great extent.

The first method employed to find the shape of the earth from measurement of arcs consisted in measuring the lengths of two meridian arcs and their amplitudes. This method gave a

different spheroid for every pair of arcs measured; for, as later developments show, the earth's surface differs from any mathematical figure by quantities greater than any probable error of measurement.

The next step in the problem was to find the best spheroid to which measurements in geodesy and astronomy might be referred. This was done by applying the theory of least squares to the results obtained from measurement.

Arc measurements began under the Greeks and Arabs, and were very crude. Picard by accident in 1660 obtained a result which we know now to be very close. The most trustworthy measurement of the earth's elements of form are considered to be those of Col. A. R. Clarke, made in 1880.

The U. S. Coast and Geodetic Survey have measured two arcs, one along the 39th parallel and the other an oblique arc along the eastern coast. A comparison of results obtained from these measurements with those obtained by Clarke and Bessel shows that we still require a much wider investigation to reconcile completely astronomical and survey determinations.

In the geodetic survey of Canada just begun it is to be hoped that, as we can profit by the labors of the world's greatest scientists and the results which other countries have gained at considerable cost, we may be able to add something to what is already known about the form and magnitude of the earth.

At the close of Mr. Smith's paper a brief discussion was entered into by Dr. Klotz and Dr. King, both of whom emphasized the importance and need of a Geodetic Survey of Canada.

March 11.—The meeting was held in the Normal School Hall at 8 P.M.

Professor H. T. Barnes, of McGill University, gave a paper on "The Electron Theory of Matter."

Professor Barnes introduced his subject by discussing briefly the properties of matter and of ether, giving reasons why ether was considered to exist. Ether is now thought to be a very dense fluid, incompressible, non-viscous, possessing no friction

and abounding in energy. Matter itself may be composed of ether, or rather may be a certain form of ether.

Lord Kelvin's theory of matter being simply vortex rings of ether, and that the different elements may be different arrangements of the vortex rings was then illustrated and discussed. Examples of vortex rings of smoke in air and of colored water in clear water were shown, and the action of rings meeting, or overtaking other rings noted. Vibrating rings were produced from an elliptical orifice.

The limit of the divisibility of matter, or the molecule, had been measured by Lord Kelvin in four independent ways with the same result, 10^{-8} cm. Professor Barnes then pointed out that if we measure mass by the velocity given to it by a known force the result will vary according as the resistance to the motion is greater or less.

The lecturer then outlined how the atom of electricity or the electron was discovered. The electrolysis of substances showed that a definite current of electricity gave a definite deposit of any substance, called its electro-chemical equivalent.

The atomic weight of any substance divided by its electro-chemical equivalent gives a constant quantity, a fundamental constant.

If a charge of electricity is passed through an exhausted tube certain phenomena result. That radiant particles of matter are sent off from the cathode or negative pole is shown by their action under a magnet and in other ways. Goldstein also showed that particles were sent from the anode and that a magnet deflects them in an opposite direction to that in which it deflects the cathode particles.

In attempting to obtain the fundamental constant for these particles it was found that while a normal result was obtained for the anode particles, the cathode particles gave a result 1000 times too great. The next thing to do was to find out whether the atomic weight of the electro-chemical equivalent could be measured. By a series of beautiful experiments the value of the

electro-chemical equivalent was found to be normal. The physicists were therefore forced to the conclusion that the atomic weight of the particles streaming from the cathode was $\frac{1}{1000}$ smaller than the normal. These minute particles were called electrons, and in spite of the objections of chemists and molecular theorists, it is considered that they are $\frac{1}{1000}$ of the mass of the atom of hydrogen. From the electro-chemical equivalent and the mass the size of the elctron 10^{-13} cm. was deduced.

The comparative size of the electron and the molecule was illustrated by enlarging the molecule to the size of the solar system, in which case the electron would be as large as the earth. The enormous force with which two electrons repel each other was given. The lecturer pointed out that a whole theory of matter could be built up; the free electrons gave us electricity. He briefly explained some of the commoner manifestations of the presence of electricity.

At the close a vote of thanks was given to the lecturer.

March 25.—Miss Anna E. Rudman was elected a member of the Society.

Dr. Ralph E. De Lury then read a paper on "Convection as a Factor in Stellar Variation."

The object of this paper was to discuss the periodic light-variations of stars, attributing them to periodic disturbances in the atmospheres of the stars caused by the orbital motion of satellites, and ascribing the different classes of variation to atmospheres of different character.

Before the discovery of the telescope few observations of the color and brightness of stars were made. After its discovery astronomers soon detected variations in the brightness of stars and began to study the causes of the variations. Photography has been a great aid in the study.

Dr. De Lury then classified the stars according to their light variation, giving typical light-curves of the different classes. Some theories to account for these variations were given. Sometimes the changes were thought to be due to an eclipsing of the

star by a darker companion; in other cases to the ellipsoidal form of a rotating star, in others to be a "world on fire." But the larger class of variables seemed to owe their variation to a change in the atmospheres of star and companion. Another explanation of all the classes of stellar variation is based upon the hypothesis that the stars are clusters or swarms of meteorites.

The spectrocopic observations go to show that, generally speaking, there are changes in the spectral lines accompanying changes in intensity of light, and also that the character of these changes depends on the chemical constitution of the star. The length of period also may be a factor in determining the character of the variation. Furthermore, it is natural to assume that the periodicity of the variation is dependent on the basic orbital or rotational periods involved in the system under observation. Consequently it seems plausible to assume that periodic light variations are due to changes in the action on the atmosphere of the varying star introduced in the orbital or rotational period and that the character of these light variations depends on the nature of the periodic atmospheric changes which in turn depend on the chemical constitution of the atmosphere.

A consideration of the atmospheric conditions of a star leads us to the conclusion that there exist convection currents radiating from the interior and that these may give rise to a rotational motion of the star. The presence of a satellite revolving in an elliptical orbit would introduce periodic changes in the convection currents which in turn would cause periodic changes in the light of a star.

The paper then discussed at length the conditions existing in the atmosphere of the Sun. The evidence of planet action upon spots is not sufficiently striking to be thoroughly convincing. Both the sun-spot curve and the light-curve of many stars, however, show a more rapid rise to maximum than fall to minimum. It is reasonable to assume that this slow sinking-away to minimum is due to an induced effect, *i.e.*, the cause produces an effect, and this effect produces another effect. Upon this

assumption many of the peculiarities of the light-curves of stars can be satisfactorily explained, assuming, further, that the irregularities of the sun-spot variations are caused to a large extent by the whims of the atmosphere itself. Some astronomers believe that solar spots and the phenomena of variable stars are produced by similar agencies.

At the close of the paper a brief discussion took place in which it was emphasized that anomalies were often considered to be errors of observation whereas they really existed.

April 1.—The meeting was held in the Normal School at 8 P.M. Dr. Otto Klotz introduced Mr. James White, F.R.G.S., Geographer to the Canadian Government, who, he said, is well known throughout the world, and who addressed the meeting on "Map-Making in Canada."

Mr. White first commented upon the difference between map-making in Canada and in Europe, where information for the map-maker is accurate and reliable : in Canada the data are not all reliable, but vary in accuracy from the trigonometrical and Dominion land surveys to the sketches drawn by the intelligent Indian.

After the information has been carefully plotted on paper a tracing is made, which is sent to the engraver, who puts the work on a copper plate. A transfer of this is made to stone from which the actual printing is done.

Mr. White then reviewed the history of map-making from the earliest times, giving special attention to all the earlier maps dealing with either America or Canada. In 1899 the position of Dominion Geographer was created, Mr. White being appointed to the position, with instructions to compile an 8-sheet map of Canada on a scale of 35 miles to an inch. Since its completion other maps of different portions of the country on other scales have been begun and are now under way.

In conclusion Mr. White spoke of the geographer as being at once a patriot and an internationalist, one of whose most important duties it was to remove prejudices and foster good feeling among the nations and races of the world.

A vote of thanks to Mr. White was moved by Mr. Joseph Pope and seconded by Dr. W. Saunders. The formal meeting then broke up, but nearly all those present took advantage of the invitation extended by Mr. White to examine the maps and plans which were arranged in the front of the room. They were interesting not only from an historical and geographical point of view, but also from the fact that they showed the progress which had been made in engraving, printing and book-making during the last 250 years.

C. E.

AT PETERBOROUGH.

February 26.—The first meeting of the Peterborough Centre for the year 1909 was held in the Collegiate Institute building.

The local vice-president Mr. H. B. Collier occupied the chair, and after outlining the course of lectures provided for the spring term, introduced the speaker of the evening, Professor C. A. Chant, of the University of Toronto.

The lecturer addressed the meeting on "The Universe of Stars." In clear untechnical language he explained the structure of the universe, and all present were able to follow the discussion. The lecture was illustrated with many beautiful slides showing views of constellations, clusters, nebulæ as well as various spectrographic effects.

A vote of thanks was tendered the speaker on motion of Rev. G. W. Henderson and Mr. T. A. S. Hay. In reply Professor Chant congratulated the Society on having such a splendid building for meetings, and urged upon the officials the necessity for continued efforts, regardless of small attendance and other discouragements.

The long and tedious illness of Rev. Dr. Marsh, the local president, was a matter of much concern to the Society, and on motion of Mr. T. A. S. Hay, seconded by Mr. H. O. Fisk, it was carried unanimously that a vote of sympathy, and a hope for speedy recovery be tendered Dr. Marsh. The Secretary was instructed to convey the motion as passed.

March 9.—Mr. H. B. Collier the local vice-president was in the chair.

Mr. G. Parry Jenkins of Hamilton gave an illustrated lecture on "Skyland." In his introductory remarks he regretted that the local president Dr. Marsh was unable to be present, owing to his protracted illness; and he conveyed greetings from the Hamilton Centre, having been deputed to do so at a meeting held the previous evening.

In his trip to Skyland Mr. Jenkins showed at every stage of the journey a thorough acquaintance with the various realms visited. Through plain language and many lantern views the subject was treated in a very entertaining manner and the speaker held the undivided interest and attention of the representative gathering who accompanied him on his imaginary journey.

The lantern was in charge of Mr. H. O. Fisk. At the close a hearty vote of thanks, on motion of Messrs. A. W. Patterson and T. A. S. Hay, was tendered Mr. Jenkins.

E. F.

At Hamilton

February 2.—Six more applications for membership were received, one of which, from Hon. J. M. Gibson, Lieutenant-Governor of Ontario, the Society felt specially honored in receiving.

Vice-President William Bruce then took the chair and called on the local president G. Parry Jenkins, F.R.A.S., for his lecture on "The Telescope and its Revelations."

To illustrate the first part of his subject Mr. Jenkins had with him the handsome three-inch refractor belonging to Mr. Bruce, which was the workmanship of a former president of the Hamilton Society, Rev. Dr. Marsh.

He told the interesting story of the invention and development of the telescope from the spy-glass of Galileo to the giant equatorial of to-day, and explained the construction and principles of the more important instruments.

The speaker then outlined the revelations which each improvement in the telescope brought to man. He illustrated these

epoch-making discoveries by a number of lantern slides of celestial objects, and told many of the stories which are forever associated with them.

At the close, in proposing a vote of thanks to Mr. Jenkins, Rev. J. J. Morton and Mr. C. P. Oliver expressed the thanks of the large audience for the very interesting lecture, which was the more appreciated because the speaker was the President of the local centre.

March 8.—Mr. Wm. Bruce, local vice-president, gave the first part of a paper on "The Artistic Side of Astronomy."

Mr. Bruce's lecture was an account of a supposed trip in a twentieth century air-ship. He started from the top of the mountain at Hamilton, taking all the members of the Society with him, and visited first the finest examples of terrestrial scenery in America and Europe. Then leaving the earth he took his guests to the Moon and Venus. The descriptions of terrestrial, lunar and planetary landscapes as seen from the air-ship were fascinating.

In the course of the paper he wove in accounts of interesting incidents from his personal experience with many touches of humor. He pictured well known members of the Society, overcome by the various sights which they witnessed, as bursting forth into song and reciting selections from the poets describing the wonderful scenes.

The second part of Mr. Bruce's paper will be awaited with much interest.

Six more applications for membership were received at this meeting.

March 23.—The lecture of Rev. J. J. Morton, entitled "Swedenborg on the Earths in the Universe," while an unusual one for an astronomical society, was nevertheless very interesting. The ground covered was really much more than the title implies. It included an outline of the life and work of Swedenborg, an explanation of the theology for which his name stands to-day and his description of the conditions of life on the worlds which he claimed to have visited.

Mr. Morton approached the subject from a sympathetic point of view and for this reason his lecture afforded an unusual opportunity of hearing, as he said, "the other side" put in a very clear and forceful way.

Swedenborg (1688–1772) was recognized as a prominent scientist of his day and he certainly anticipated several scientific discoveries of his successors, but whether this was due to an exceedingly brilliant imagination or to a vision is a matter of opinion. Whatever truth may be in his theology, there are many things in his account of his visits to the Moon and the planets which astronomers know are not only contrary to theory but do not agree with ascertained facts.

In the friendly discussion which followed the lecture, Mr. H. B. Witton, Mr. G. P. Jenkins and others spoke very highly of the paper as a whole, although they could not indorse all that had been said.

April 5.—The Society this evening had the pleasure of hearing Professor S. A. Mitchell of Columbia University give a lecture entitled "An Astronomer in Spain." The meeting was held in the recital hall of the Hamilton Conservatory of Music, as the usual place of meeting could not accommodate the large audience. The chair was taken by Mayor McLaren, who introduced Professor Mitchell as a "Canadian boy."

The lecture was an account of one of the parties of the American expedition to Spain to observe the eclipse of the Sun in August, 1905. It was illustrated by many fine lantern slides of photographs taken during the trip.

The observations made by this party were very successful and the results as summed up and explained by the lecturer were very interesting and instructive.

On the motion of Mr. Wm. Bruce and Mr. Geo. Black a hearty vote of thanks was tendered the speaker.

April 14.—Rev. M. J. Rosa, C.M., Professor in the Niagara University, gave a lecture on "The Niagara Frontier."

At the beginning of his address Father Rosa called attention to the fact that since the Niagara mountain or escarpment was geologically part of the Laurentian formation it was probably the first dry land to rise above the waters when the command went forth "Let the dry land appear." He then drew a vivid word picture of the terrific war of the elements which must have taken place from that time until the earth had cooled sufficiently to allow life to exist on it.

The balance of the lecture dealt with the history of this frontier region from the time of the mound builders to the present day; a history rich in story and legend, for around this section of the country centred many of the struggles which took place in the development of North America.

The discussion which followod the lecture was on the geological questions of the age of Niagara Falls, the age of the earth and of the solar system, and many interesting points were brought out. A very hearty vote of thanks was tendered Professor Rosa, on the motion of Mr. J. G. Cloke and Rev. J. J. Morton.

At the opening of the meeting the President exhibited thirteen lantern slides made from photographs of the Moon and the Morehouse Comet taken at the Dominion Observatory, Ottawa. The slides showed the splendid work which was being done at the Canadian observatory.

The Society had the pleasure of having present as a visitor Mr. J. R. Collins, of Toronto, general secretary of the R.A.S.C., and his words of greeting and his contribution to the discussion of the lecture added a great deal to the interest of the meeting.

E. H. D.

NOTES FROM THE DOMINION OBSERVATORY

Astrophysics

The new single-prism spectrograph referred to in the last issue of these notes has now been in regular use for some time and performs very satisfactorily. Besides the complete elimination of flexure as described in the last issue, temperature changes within the body of the spectrograph proper must be vanishingly small owing to the satisfactory working of the automatic heating arrangement, to the smoothing-down of the minor remaining irregularities by the half-inch-thick covering of felt and to the careful heat insulation introduced in the shafts connecting the spectrograph to the supporting cradle.

Owing to the possibility of using a wider slit, still maintaining the same purity of spectrum, the exposure time is considerably reduced over that required for the previous instrument, thus increasing the output and range of the equipment.

The elements of the orbit of the spectroscopic binary *η Bootis* (R. A. $13^h\ 49{\cdot}9^m$, Decl. + 18° 54′, Photographic Magnitude 3·8, Spectral Type XIV*a*) have recently been determined by Mr. W. E. Harper from the measures of 45 plates obtained at Ottawa, using also some previous measures of other observatories. The final elements obtained by least square solutions are as follows:—

Period	U = 489·14 days
Eccentricity	e = 0·3817
Half amplitude	K = 9·90 km.
Longitude of apse	ω = 319°·64
Velocity of the system	γ = − 0·17 km.
Periastron passage	T = J. D. 2,417,751·54
Projection of major semi-axis	$a \sin i$ = 30,773,620 km.
Max. positive velocity in orbit	A = 12·78 km.
Max. negative velocity in orbit	B = 7·0 km.

The elements of the orbit of the spectroscopic binary *α Corona Borealis* (R. A. $15^h\ 30{\cdot}4^m$, Decl. $+\ 27°\ 3'$, Photographic Magnitude 3·4, Spectral Type VIII*ab*) have been determined by Mr. J. B. Cannon from 103 plates obtained at Ottawa. The velocities of these plates were obtained by considering the hydrogen lines and the *K* (λ 3934) line only, as the *Mg* line (λ 4481·400) gave discrepant values, and was consequently omitted in striking the mean. The resulting elements are :—

Period	$U = 17{\cdot}355$ days
Eccentricity	$e = 0{\cdot}277 \pm {\cdot}0012$
Half amplitude	$K = 32{\cdot}97$ km.
Longitude of the apse	$\omega = 303°{\cdot}68 \pm 4°{\cdot}25$
Velocity of the system	$\gamma = +\ 0{\cdot}498 \pm 0{\cdot}330$ km.
Periastron passage	$T =$ J.D. $2{,}417{,}725{\cdot}054 \pm 0{\cdot}187$
Projection of major semi-axis	$a \sin i = 7{,}560{,}000$ km.
Max. positive velocity in orbit	$A = 38{\cdot}033$ km.
Max. negative velocity in orbit	$B = 27{\cdot}905$ km.

Both of these orbits will be discussed later when the details are published in full.

J. S. P.

The Seismograph—Bosch Photographic, 200 Grammes—Magnification 120.—In the last Notes an earthquake for January 23 was reported. Since then reports of the same quake have been received from a number of other stations, as will be seen from the subjoined table. An attempt has been made to determine the time of the occurrence at the epicentre, based on the Press despatch that the epicentre was at Bahrein, Persia, and on the times of arrival of the first and second preliminary tremors (*P* and *S*) at the various stations. The geographical position of Bahrein is taken from Stieler's *Hand Atlas*, $\varphi = 33°\ 30'$, $\lambda = 49°\ 30'$ E. Greenwich. The distances are taken from our 30-inch globe.

The computed transmission times V_1, V_2 for the *P* and *S* are interpolated from the Wiechert-Zœppritz values compounded from the Indian earthquake of 1905, the Calabrian one of 1905, and the San Francisco one of 1906. For *L* the velocity is taken at 4 km. per second.

Earthquake of January 23, 1909

BAHREIN, PERSIA

$\varphi = 33° 30'$, $\lambda = 49° 30'$ E. OF GR.

GREENWICH TIME

Station	Distance km.	Ordinate km.	Seismograms			Computed			Deduced time at Epicentre		
			P	S	L	V_1	V_2	B	$P-V_1$	$S-V_2$	$L-B$
			h m s	h m s	h m s	m s	m s	m s	h m s	h m s	h m s
Ottawa	9750	1778	3 01 13	3 11 42	3 28	12 54	23 38	40 37	2 48 19	2 48 04	2 47 23
Hamburg	3830	287	2 55 14	3 00 36	3 03 12	7 07	12 40	15 57	4 807	4 756	4 715
Aachen	4020	315	2 55 33	3 01 05	3 04 56	7 21	13 06	16 45	4 812	4 759	4 811
Trieste	3330	217	2 54 42	2 59 42	3 04 41	6 22	11 22	13 52	4 820	4 820	5 049
Sarajevo*	2920	168	2 55 30	3 00 09	3 03 36	5 52	10 24	12 10	4 838	4 845	5 026
Cracow	3060	183	2 54 08	2 58 59		6 00	10 43		4 808	4 816	
Vienna	3200	200	2 54 18	2 59 10	3 00 56	6 13	11 07	13 20	4 805	4 803	4 736
Tiflis	1030	21	2 50 40			2 19	4 04		4 821		
Strassburg	3850	290	2 55 09	3 00 26	3 05 26	7 09	12 40	16 02	4 800	4 746	4 924
Laibach	3300	213	2 54 20	2 59 15	3 04 17	6 21	11 16	13 45	4 759	4 759	5 032
Belgrade	2650	137	2 53 26	2 57 53	3 01 42	5 27	9 42	11 02	4 759	4 811	5 040
Cartuja	4820	450	2 56 33	3 03 05	3 07 30	8 20	14 48	20 05	4 813	4 817	4 725
Washington	10300	1972	3 01 22	3 12 05	3 30	13 18	24 28	42 55	4 804	4 737	4 705
							Mean		2 48 11	2 48 06	2 48 48

* Times evidently one minute too late.

It will be observed from the above table that the mean time deduced from the P agrees within 5 seconds of the mean of the deduced time from the S, so that one feels justified in giving for the time of the occurrence of the quake in Persia $2^h\ 48^m\ 8^s$ Greenwich time. The agreement between the two independent values $P - V_1$ and $S - V_2$ for any station is satisfactory too; in several cases the times are absolutely co-incident. However, we cannot always be sure of individual seconds in reading P and S on the seismogram.

A greater difficulty we encounter when trying to read on the seismogram the arrival of the long waves, L, and this is manifested in the last column, which in the ideal condition we should expect to agree with the other two. The discordances in the last column of individual values from the general mean ($2^h\ 48^m\ 08^s$) of the other two columns is not attributable to the assumption of 4 km. as the velocity of the long waves per second, but rather to the reading of the various seismograms. For, tak-

ing $T = 2^h\ 48^m\ 08^s$ as the time of the occurrence of the quake and solving by least squares for the velocity of the long waves we get 238 km. per minute, which is practically the same as 4 km. per second, the quantity used.

If we arrange $L - T$ in the order of magnitude and divide the resulting time into the respective distance of the station from the epicentre it will be found that there is a tendency, for the greater distance to give the greater velocity; the extreme values being Hamburg 4·24 km., and Belgrade 3·26 km. per second.

We may recall the table of the Calabrian or Messina quake published in the last number, which gave for Belgrade 3·36 km., and for Hamburg 3·55 km., and the general mean 3·27 km. In no case for that quake was a velocity obtained as high as 4 km., the highest being for Cartuja 3·61 km. per second.

Judging from our seismograms here, it is believed that the discordances obtained for the velocity of the long waves is mostly or wholly attributable to the uncertainty of identifying, midst the complexity of longitudinal and transverse waves and their reflections which precede, the arrival of the surface or long waves.

Some of the stations on this continent failed to get a record of the first preliminary tremors, due to lack of sensitiveness of the instrument. For distant quakes not only the diminished force of the longitudinal impulse comes into play but also the horizontal component of that impulse, so that distance very materially militates against the recording of the first preliminary tremors.

The following earthquakes have been recorded since the last Notes were sent:—

February 9	N–S Component	E–W Component
	h m	h m
First trace of waves	12 01 ? G.M.T.	12 01 G.M.T.
Long waves		12 06 (period 20s)
End	12 21 ?	12 21

Well-marked microseisms were present

February 16

	N–S Component	E–W Component
	h m s	h m s
1st P. T.		16 31 20? G.M.T.
2nd P. T.		
P. P.	16 54 20 (period 6s)	16 54 20 (period 6s)
Maximum	16 55	16 55 40
End	17 35	17 35

Epicentre distant 8,400 km.

February 22

	h m s	h m s
1st P. T.	9 40 ? G.M.T.	9 40 00 G.M.T.
2nd P. T.	9 45 08	9 45 06
P. P.	9 47 00	9 48 29 (period 7s)
Maximum		9 52 40
End	11 20	11 37

Epicentre distant 3,500 km. Microseisms present.

February 26

	h m s	h m s
1st P. T.	16 53 35 G.M.T.	16 53 35 G.M.T.
2nd P. T.	16 59 16	16 59 16
P. P.		17 01 23
Maximum		17 05 12 (period 12s)
End	17 37	17 38

Epicentre distant 3,900 km. Well-marked microseisms present.

March 12 13

	h m s	h m s
First trace of waves	23 42 00	23 42 16
Long waves	0 07	0 07
Maximum		0 14 (period 20s)
End	1 22	1 38

March 13

	h m s	h m s
1st P. T.	14 42 20 G.M.T.	14 42 28 G.M.T.
2nd P. T.	14 52 40	14 52 39
P. P.	15 17	15 16 32 (period 20s)
Maximum	15 22	15 19 30 (" 27s)
End	17 00	17 00

Epicentre distant about 9,500 km.

March 18

	h m s	h m s
1st trace of long waves	0 03 40 G.M.T.	0 03 40 G.M.T.
End	0 20 ?	0 20 ?

Irregularities due to wind, and microseisms mask the phases.

April 10

	N–S Component	E–W Component
	h m s	h m s
1st P. T.	G.M.T.	5 44 38 ? G.M.T.
2nd P. T.	5 53 34 ?	5 55 16
P. P.	6 16 20	6 17 32
Maximum	6 24	6 26 (period 20s)
End	7 10	7 30

Epicentre about 10,000 km. distant.

April 10

	h m s	h m s
1st P. T.	18 56 35 G.M.T.	G.M.T.
2nd P. T.	19 04 24	19 04 26
P. P.	19 16 ?	19 14
Maximum	19 22 (period 14s)	19 20 (period 14s)
Another maximum	20 27 (" ")	20 24 (" ")
End	21 00	21 00

Epicentre distant 6,300 km.

The absence of the E–W component for the 1st P. T. or longitudinal waves would seem to indicate that the epicentre lies on or near the meridian of Ottawa.

April 16

	h m s	h m s
1st P. T. (?)	3 30 38 G.M.T.	3 31 (?) G.M.T.
2nd P. T.	3 33 20	3 33 20
P. P.		
End	3 45	3 45

Epicentre distant about 1,600 km.

O. K.

NOTES FROM THE METEOROLOGICAL SERVICE

Earthquake Records by Milne Seismograph

TORONTO OBSERVATORY

R. F. Stupart, Director

P.T. = Preliminary Tremors; L.W. = Large Waves. Time is Greenwich Civil Mean Time
0 or 24 H = midnight.

No.	Date 1908	P. T. Commence	L. W. Commence	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
802	July 8	13 16·7			13 26 2	0·25	0 9·5	
803	" 13	21 42·6			21 58·7	0·25	0 16·1	
804	" 16	17 8·5			17 13·5	0·2	0 5·0	
805	Aug. 14	0 57·7		1 1·7	1 41·7	2·0	0 44·0	Well defined
806	" 17	10 56·8 ?) 11 04·2)		11 15·2	13 34·5	1·0	?2 37·7	Prolonged
807	" 19	0 49·6			1 0·6	0·05	0 11	
808	" 20	10 43·8			11 6·8	0·2	0 23·0	
809	" 22	20 25·2			20 37·5	0·05	0 12·3	
810	" 29	18 24·0			18 52·0	0·4	0 28·0	
811	Sept. 4	17 13·8			17 23·6	0·1	0 9·8	
812	" 21	6 57·8) 7 01·8)	7 9·5	7 36·2	8 26·8	2·0	1 29·0	
813	" 24	0 12·9			0 14·0	0·05	0 1·1	
814	" 24	18 58·0			19 4·5	0·1	0 6·5	
815	Oct. 10	15 26·3			15 44·8	0·4	0 18·0	
816	" 13	5 13·1	V_2 5 18·5) B 5 27·1)	5 33·2	? 7·0	3· 4	1 46·9	
817	" 13	Mixed up with last quake	7 3·6	7 5·9	7 21	0·3	0 15·0	An increase in [vibs. from [last disturb.
818	" 14	15 18·6			Lost att'ding instr'm't	0·8	—	
819	Nov. 2	5 55·1			5 59·5	0·05	0 4·4	
820	" 2	6 31·3	6 35·8		7 1·3	0·6	0 30 0	Heavy quakes [reported from [Europe
821	" 6	7 32·0) 42·0)	7 53·9	8 5·2	8 55·5	2·5	1 23·5	
822	" 6	14 4·5			14 52·0	0·5	0 47·5	
823	" 6	23 13·5			23 24·0	0·1	0 10·5	
824	" 9	15 29·0?			15 31·0?	0·03	0 2·0	Just noticeable
825	" 11	13 55·3			?	0·05	–	
826	" 30	21 55·0	21 56·0	21 57·1	24 2·0	6·5	2 7·0	Hy. Queen [Charlotte Is.
827	Dec. 12	13 21·5	13 59·7	14 5·6	14 45·5	0·9	1 24·0	
828	" 25	21 44·6			21 49·6	0·2	0 5·0	
829	" 28	4 31·2	V_2 4 39·8) B 5 00·0)	5 2·1	?6 43·5	1·8	2 12·3	Dest'ive Cala- [brian quake

Period to 10th December . 14·8 sec. 1 mm. = 0″·66
" 10th December to 16h of 12th 15·2 "
" Afterwards 14·9 " 1 mm. 0″·70.

Earthquake Records by Milne Seismograph

Victoria, B. C.

Baynes Reid, Superintendent

No.	Date 1908	P. T. Commence	L. W. Commence	Max.	End	Max. Ampl.	Duration	Remarks
		h m	h m	h m	h m	mm.	h m	
816	July 8	13 14·3			13 43·3	0·6	0 29·0	
817	" 16	17 12·3			17 15·5	0·1	0 3·2	
818	Aug. 12	16 7·1			17 0·9	0·05	0 53·8	[defined
819	" 14	0 34·2	1 2·7	1 4·3	1 36·7	2·0	1 2·5	Small, well
820	" 17	10 58·5			13 16·5	0·7	2 18·0	Prolonged
821	" 18	11 3·0			11 11·0	0·3	0 8·0	Eureka, Cal.
822	" 19	1 5·0			1 16·5	0·65	0 11·5	
823	" 20	10 42·6			11 14·4	0·5	0 31·8	
824	" 22	19 31·7			19 37·7	0·15	0 6·0	Two
825	" 27	14 51·9			14 55·9	0·05	0 4·0	[very small
826	" 29	18 45·6			19 11·9	0·05	0 26·3	[quakes
827	Sept. 4	17 20·6			17 34·6	0·05	0 14·0	
828	" 17	18 48·4			8 52·4	0·15	0 4·0	
829	" 21	6 44·3	6 52·0	6 55·5	8 18·5	1·3	1 34·2	Small and
830	" 24	1 25·4			1 30·4	0·05	0 5·0	[prolonged
831	Oct. 7	4 9·8			4 16·8	0·15	0 7·0	
832	" 10	15 5·7			15 44·7	0·5	0 39·0	
833	" 13	5 13·7	5 19·6) 5 26·5)	5 29·1	?7 00	13·0	1 46·3	Large
834	" 13	7 1·0	7 2·4	7 4·0	?7 40	5·0	0 37·6	Sudden in-
835	" 14	15 18·3	15 23·8	15 26·7	15 54·5	1·7	0 36·2	[crease in
836	" 20	3 16·5			3 18·5	0·05	0 2·0	[vibs.
837	Nov. 2	5 45·2			5 48·7	0·1	0 3·5	
838	" 2	6 9·7			7 11·7	0·5	1 2·0	
839	" 6	7 28·5	7 47·0	7 49·5	9 1·0	1·2	1 32·5	
840	" 6	13 58·5			15 1·5	1·0	1 3·5	
841	" 6	23 24·5			23 33·5	0·1	0 9·0	
842	" 9	15 57·8			16 5·8	0·3	0 8·0	
843	" 11	13 42·9			13 52·8	0·1	0 9·9	
844	" 11	14 42·8			14 49·3	0·05	0 6·5	
845	" 30	21 38·4	21 40·7	21 42·0	22 37·9	?19·5	0 59·5	Queen Char-
846	Dec. 12	13 18·8	13 54·8	13 55·5	14 38·3	0·6	1 19·5	[lotte Is.
847	" 12	21 10·1			21 19·3	0·05	0 9·2	
848	" 18	16 17·7			17 4·7	0·15	0 47·0	
849	" 28	(4 33·2 (P)	4 43·6)	5 19·6	6 11·6	2·6	1 38·4)	Dest. Cala-
		(4 39·8	5 6·6)				1 31·8)	[brian quake

Period 15 seconds

1 mm. = 0″·76

J. Y.

Erratum.

In the report by J. Young, p. 72 of the last issue, the time of the shock at Messina should have read $5^h\ 20^m$, and the speed of the preliminary tremors to Toronto and Victoria 11·2 km. and 12·1 km. respectively.

Summary Report of the Weather in Canada
February, 1909

Temperature.—The mean temperature of February was above the normal in the more southerly portions of all the Provinces and below the normal in the northern portions. This was especially pronounced in Alberta where in the south the positive departure was about 2°, while in the north the negative departure was from 5° to 7°; also in Ontario where in the Southwestern Counties the positive departure was from 6° to 8°, while in the Upper Ottawa Valley the negative departure was 3°. The contrast between south and north was less pronounced in the Maritime Provinces than elsewhere, with the greatest excess of the average 2° at St. John.

For the highest and lowest temperatures see the accompanying table.

Precipitation.—The precipitation was considerably in excess of the average in Ontario and over the larger portion of Quebec, while in the Maritime Provinces and also in the West, departures from average were not pronounced in either direction. The most striking feature was probably the large rainfall in the St. Lawrence Valley, heavy rains having occurred on several days. In Ontario and the Maritime Provinces days of rain and snow were nearly equally divided.

Depth of Snow.—At the close of the month the ground was generally snow-covered throughout Canada, but the amount varied considerably with the district.

A depth of about 1 inch near the Bay of Fundy increased northward to about 60 inches over the greater portion of Quebec, and in the Cariboo District of British Columbia there was about 40 inches on the ground. In other portions of Canada the depth varied between a trace and 15 inches.

On the 1st of March, reports from the Gulf of St. Lawrence show that the ice was closely packed from Anticosti to the Magdalen Islands, while between the latter place and Cape St. Lawrence there was a heavy open ice field.

MARCH, 1909

Temperature.—The mean temperature for March was generally above the average in Canada, although in portions of British Columbia, the major part of Ontario and over Quebec, the normal value was either not quite, or just, reached. Departures from average in the Western Provinces ranged between 2 and 8°.

For the highest and lowest temperatures at various stations see the accompanying table.

Precipitation.—The precipitation recorded in Canada during March was less than the usual quantity except over a large portion of Ontario, Eastern Quebec, and the Maritime Provinces, where the normal amount was slightly exceeded.

Depth of Snow.—On the last day of the month the ground over a large portion of Canada was snow covered. In British Columbia, the higher levels were well covered, also the northern districts of Alberta. In Saskatchewan and Manitoba there was a depth of from 3 to 7 inches. Northern Ontario recorded from 5 to 11 inches, elsewhere in the Province the ground was practically bare. A depth of 16 inches at Montreal increased eastward to 52 inches at Quebec. New Brunswick also was largely snow-covered, the depth decreasing rapidly southward to a trace near the Bay of Fundy.

R. F. S.

Temperatures for February and March

Station	February		March	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	13·2	-53	46	-25
British Columbia				
Agassiz	50	15	71	30
Atlin	35	-41	43	- 8
Barkerville	39	-31	52	5
Kamloops	56	- 9	67	22
New Westminster	50	20	62	28
Vancouver	52	23	58	28
Victoria	54	28	56	30
Western Provinces				
Banff	39	-38	47	- 6
Battleford	34	-38	42	-15
Calgary	46	-35	58	3
Carberry	30	-44	40	-20
Edmonton	42	-39	59	-19
Medicine Hat	50	-26	61	0
Minnedosa	27	-35	38	-22
Moosejaw	40	-30	51	- 9
Morden	27	-25	41	-13
Oak Bank	28	-40	40	-23
Portage la Prairie	33	-29	38	-20
Prince Albert	30	-37	44	-18
Qu'Appelle	40	-35	46	-14
Regina	38	-34	39	-13
Swift Current	48	-28	49	- 8
Winnipeg	29	-34	38	-19
Ontario				
Agincourt	48	-10	47	7
Alton	45	-16	40	- 4
Aurora	46	-15	48	2
Bancroft	46	-23	45	- 5
Beatrice	43	-18	40	- 6
Birnam	48	0	44	10
Bloomfield	46	-13	40	4
Brantford	50	-10	46	6
Bruce Mines	42	-16	45	- 9
Chatham	52	- 1	51	13
Clinton	47	0	39	8
Cottam	52	- 2	55	13
Cockburn Island	43	-12	45	- 7
East Toronto	44	-11	49	4
Gravenhurst	44	-22	41	- 9
Haliburton	44	-19	42	- 8
Hamilton	50	- 8	47	12
Huntsville	64	-15	54	- 3
Kenora	29	-37	43	-14
Kinmount	43	-20	42	-16
Kingston	44	-11	49	8
Lakefield	45	-15	45	3
London	50	- 3	46	12
Lucknow	46	- 2	39	3
Meaford	50	2	40	3
Midland	50	0	52	8
North Gower	48	-15	-	2
Otonabee	45	-15	40	7
Ottawa	44	-15	43	- 3
Owen Sound	48	- 4	42	2
Paris	47	- 6	45	12
Parry Sound	46	-15	42	- 2
Peterboro'	47	-18	40	0
Point Clark	45	5	51	20
Port Arthur	38	-26	46	- 5
Port Burwell	41	- 8	48	12
Port Dover	43	- 9	46	9
Port Hope	42	-14	44	3
Port Stanley	47	1	46	11
Rockliffe	39	-29	45	-22
Ronville	48	-25	43	-15
Sarnia	49	- 4	46	8
Southampton	46	- 3	45	6
Stony Creek	52	10	49	8
Stratford	47	- 1	40	7
Toronto	46	- 9	47	7
Uxbridge	45	-14	41	- 4
Wallaceburg	54	- 2	47	12
Welland	49	- 7	46	9
White River	32	-48	44	-20
Windsor	50	0	50	17
Quebec				
Brome	46	-23	42	- 9
Father Point	34	-23	44	-14
Montreal	41	-11	42	4
Quebec	36	-16	40	- 7
Sherbrooke	47	-14	44	-12
Maritime Provinces				
Charlottetown	44	-16	45	- 1
Chatham	46	-23	41	- 5
Fredericton	46	-23	43	- 8
Halifax	47	-11	47	4
Moncton	53	-23	45	2
St. John	48	- 7	47	7
St. Stephen	48	-28	45	- 1
Sussex	52	-26	46	4
Sydney	50	-13	49	7
Yarmouth	48	5	49	12

BOOK REVIEWS

Publications of the Lick Observatory, Vol. VIII., 1908.

As Director of the Lick Observatory, 1898-1900, Professor Keeler found his chief interest in rendering effective the large reflector presented to the Observatory by Mr. Crossley of Halifax, England, and in employing it in photographing the brighter nebulæ and star clusters. As the work progressed, a study of the photographs revealed the fact that the heavens are vastly richer in nebulæ than had been supposed, and the further fact that by far the greater number of these nebulæ are of spiral structure. These discoveries have had an important bearing on cosmic theories.

At the time of the death of Professor Keeler about two-thirds of his projected work had been accomplished, and the completion of the programme devolved upon Mr. Perrine, who has proved himself to be in every way equal to the trust.

The generosity of certain friends and admirers of the late Professor Keeler has enabled the Regents of the Lick Observatory to issue in the form of a memorial volume a series of plates from the original photographs. Accompanying the plates is an account of the Crossley reflector, reprinted from the *Astrophysical Journal*, Vol. II., with a list of the nebulæ and clusters photographed, and a catalogue of new nebulæ discovered on the negatives.

The plates are excellently done, and the volume is a worthy tribute to the distinguished astronomer.

An Astronomer's Wife: The Biography of Angeline Hall. By HER SON ANGELO HALL. Baltimore, Md., Nunn & Co.; 1909. x. + 252 pp. ($1.00).

Admirers of the late Professor Hall will read with pleasure this sketch, executed with pious regard, of the gifted woman who influenced so markedly the life and career of that distinguished astronomer. Her early struggles against adverse fortunes, her faith in ideals, her scientific interests, the romantic circumstances of her meeting with the young man, yearning to science, who was to be her husband, her patience under the *angusta res* of the long years of striving, and the realization of hopes are all graphically presented.

Story of the Telescope. By ARTHUR MEE. Cardiff, Wales, Published by the Author; 1909. (6d.)

In this modest little volume of some fifty pages, the author gives a very interesting history of the discovery and the evolution of the telescope, with a list of the world's great telescopes and the more famous observatories, and a chronology of astronomy. There is in addition a list of works on astronomy and astronomical periodicals.

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ASTRONOMICAL NOTES

In discussing the dispersion of light in space, Peter Lebedew, in the *Astrophysical Journal* for March, regarding the hypothesis that the ether itself might produce dispersion without absorption, remarks that the assumption is equivalent to asserting that all our electromagnetic theories must be cast aside, since the question as to the dispersion of light in pure ether has not been overlooked, nor neglected in scientific investigation. The assumption that there is absolutely no dispersion in pure ether, forms the basis of all electromagnetic theories; countless experimental results, including cathode rays, Röntgen rays, and everything in optics support this view. It is not therefore permissible to propose that such a dispersion exists in space as a provisional astronomical hypothesis.

Regarding the history of Halley's Comet Messrs. Cowell and Crommelin have been able to satisfactorily trace its path back to the beginning of the Christian era and have found evidence of the probability of even earlier appearances.

In the *Astronomical Journal*, No. 604, Professor Lewis Boss states his conclusion, based on the results of his determinations of proper motions of fundamental stars, that thirty-nine stars in Taurus, mostly brighter than the sixth magnitude, have proper motions accurately directed to a single point in the celestial sphere, the mean deviation being $\pm 1°{\cdot}8$, forming a globular cluster about 15° in diameter with a central condensation.

In the *Proceedings of the Royal Society of Edinburgh*, Vol. XXVIII., part iii., Professor Dyson states that, as a result of his

investigations of stars having large proper motions, in all parts of the sky, the two probable directions of systematic motions are shown from his results to be towards R. A. 94°; Dec. −7, and R. A. 240°, Dec. −74 respectively. The investigation tends to confirm, and extend in general, previous work on this subject.

THE *Journal of the British Astronomical Association* of March 24, contains a note to the effect that it has been decided to form a University Astronomical Society in connection with Birmingham University, with Professor Poynting as President and Sir Oliver Lodge and Professor Dixon as Vice-Presidents. Although at present the University possesses but a meagre equipment for astronomical work, the President-elect hopes that important additions will be made in the near future.

DURING the year 1908 there have been 117 minor planets discovered or first announced as being discovered.

IN *Groningen Publications*, No. 19, Professor Kapteyn and Dr. de Sitter give the result of the determinations of the proper motions of 33,000 stars from photographic plates prepared by Professor Donner. These plates were exposed in 1897–8 and remained undeveloped until 1904–6, when they were again exposed on the same regions and then developed and the proper motions derived by measuring the displacement of different sets of images. Of the total number only three were found to have annual proper motions exceeding 0″·5.

THE current number of the *Cambrian Natural Observer* contains an appreciative reference to Mr. G. Parry Jenkins, as President of the Hamilton Centre and one of the founders of the Astronomical Society of Wales.

J. R. C.

NOTES AND QUERIES

Communications are Invited, especially from Amateurs. The Editor will try to secure answers to Queries.

Queries

1. How are the times of sunrise and sunset found?

2. Why is it that at some times (January 1–10, for instance), the time of sunrise is almost stationary while that of sunset changes regularly a minute a day? From June 21 to July 4 the time of sunset is stationary, while that for sunrise changes about a minute a day.—W. H. E.

Answers

1. The times of sunrise and sunset are as a rule calculated for the rising and setting of the upper limb of the Sun, making allowance for semi-diameter and refraction.

The effect of refraction is to accelerate the rising and retard the setting.

The hour angle of the Sun from the meridian at the time of rising or setting is the angle formed at the pole by a vertical line through the Sun's centre and the meridian of the place. A spherical triangle is thus made with the three angular points, one at the pole, one at the zenith and the third at the centre of the Sun, when the latter's upper limb is coincident with the horizon, allowing for refraction.

In the spherical triangle thus formed are given the three sides, viz., the co-latitude $(90° - \varphi)$, the Sun's polar distance $(90° - \delta)$ and the Sun's zenith distance, which, reduced for semi-diameter and refraction, is $z = (90° + s + r) = 90° 50'$, where r, the mean horizontal refraction, is taken as $34'$ and s the mean solar diameter as $16'$.

The hour angle t may then be found by the formulæ :

$$\tan \tfrac{1}{2} t = \sqrt{\left(\frac{\sin (s-b) \sin (s-c)}{\sin s \sin (s-a)}\right)}$$

where

$a = z = 90° 50'$
b = polar distance $(90° - \delta)$
c = co-latitude $(90° - \varphi)$
$s = \frac{1}{2}(a + b + c)$.

The value of t thus found is the apparent hour angle of the Sun.

When the Sun is on the meridian the *apparent* solar time is $12^h\ 0^m\ 0^s$. Applying to this the equation of time we get the *mean* solar time when the Sun is on the meridian, and further correcting this *mean* solar time for difference in longitude from the standard meridian we get the *standard* time of the Sun's meridian passage, and by subtracting and adding the value of t found by the formulæ we get the *standard* time of sunrise and sunset. Generally speaking no account is taken of the change in the Sun's declination between sunrise and sunset.

2. The effects produced on the *mean* and *standard* times of sunrise and sunset as per queries owe their origin to the varying values of the equation of time. For example, the time given in the *Canadian Almanac* on September 10, 1909, for sunrise is 5.51 a.m. and sunset 6.39 p.m., making the morning apparently half an hour longer than the afternoon. The time by a sun-dial would make the lengths of the morning and afternoon differ by a few seconds only. This peculiarity arises from the fact that our clocks keep time with the standard mean Sun and not with the true Sun, as does the sun-dial.

The following example illustrates the effect produced by the equation of time and by reducing to standard time.

Toronto, September 10, 1909.

	Sunrise				Sunset			
	h	m	s		h	m	s	
Apparent time Sun on meridian	12	0	0		12	0	0	
Equation of time	−	3	0		−	3	0	
Mean time Sun on Meridian	11	57	0		11	57	0	
Reduction to *standard* time	+	17	18		+	17	18	
Standard time Sun on Meridian	12	14	18		12	14	18	
Approximate hour angle t	− 6	24			+ 6	24		
Standard times sunrise and sunset	5	50	18	a.m.	6	38	18	p.m.

F. L. B.

PREDICTIONS FOR MAY AND JUNE

RREPARED BY R. M. STEWART

Constellations on the Meridian in May

Virgo, the sixth sign and seventh constellation of the Zodiac, is one of the largest of the constellations, having for mean right ascension about 13^h. Its brightest star is Spica, very slightly fainter than the first magnitude, which crosses the meridian on May 15 at 9.50 local time. This star, as demonstrated by Vogel, by the doubling of the lines in its spectrum, is a spectroscopic binary with a period of four days. North-west from it, about half-way to Denebola (*β Leonis*) are four third-magnitude stars, which with one of the fourth magnitude form a kind of cup-shaped group to which the Arabs gave the curious name of "The Retreat of the Howling Dog." It is quite a conspicuous feature of the constellation.

Corvus (The Crow) is a small constellation immediately to the south-west of Virgo, marked by an irregular group of four or five stars, coming to the meridian about an hour before Spica and about 10° nearer the horizon. Two are of the second and two of the fourth magnitude.

Coma Berenices (The Hair of Berenice) passes the meridian at the same time as Corvus, but much higher up, within about 20° of the zenith. It contains no conspicuous star, but is marked by a thick and irregular cluster of very faint stars, which is quite conspicuous when the Moon is absent, and is altogether unlike anything else in the heavens that is visible to the naked eye.

Constellations on the Meridian in June

Boötes (The Ploughman) was so named because it was fancied by the ancients to represent the figure of the man who holds the Plough (more commonly known as the Great Bear). An alternative name, derived from the same idea, is the Bear-Driver. Though not a wide constellation, it extends lengthwise from the equator to within 30° of the pole. Its principal star, Arcturus, may be readily located by prolonging the sweep of the handle of the Dipper. It is second only to Sirius in brilliancy, being nearly a full magnitude brighter than the strictly first-magnitude stars; it has been seen, *with the naked eye*, 24^m before sunset. Though distant about 25 light years, it has a proper motion which displaces it by the apparent diameter of the Moon in about 1000 years, while it is approaching us with a velocity of over fifty miles per second. It is of a reddish yellow color, and forms an equilateral triangle with Spica and Denebola.

Libra (The Balances), though not a small constellation, contains no star of the first or second magnitude, and only two, α and β, of the third; it is the seventh sign and the eighth constellation of the Zodiac. α passes the meridian 34 minutes after Arcturus, but much lower down, β 26 minutes after α and higher up. α lies so nearly in the path of the Sun that it is almost covered by it on the 6th of November.

Corona Borealis (The Northern Crown) is a pretty half-circle of stars not far from Arcturus to the east, but higher up. Its principal star is Alphecca, of the second magnitude. It was in this constellation that a "Nova" of the second magnitude suddenly appeared on the 10th of May, 1866. In a short time it faded to the ninth magnitude, in which condition it still remains.

Some Interesting Doubles Visible in Small Telescopes

α *Leonis* (*Regulus*). R. A. 10^h 04^m; Dec. 12° 25′; magnitudes 1·5, 8·4; distance 3′; common proper motion, hence probably physical connection; smaller component has also companion of thirteenth magnitude, distance 3″.

γ Leonis. R. A. $10^h\ 15^m$; Dec. 20° 18′; magnitudes 2, 3·5; distance 3″·6; binary of 407 yrs. period; colors yellow and greenish red; very fine object.

17 *Comæ Berenicis.* R. A. $12^h\ 24^m$; Dec. 26° 25′; magnitudes 5 and 6; distance 145″; smaller component has also companion of thirteenth magnitude, distance 2″.

γ Virginis. R. A. $12^h\ 37^m$; Dec. −0° 57′; magnitudes 3·3; distance 6″; binary of 180 yrs. period; distance has been widening ever since 1836, when they were so close as to be practically inseparable.

35 *Comæ Berenicis.* R. A. $12^h\ 49^m$; Dec. 21° 44′; magnitudes 5, 7·8, 9; distances 1″·2, 29″; a triple star; the close pair at least are physically connected.

θ Virginis. R. A. $13^h\ 05^m$; Dec. −5° 03′; magnitudes 4, 9; distance 7″; another companion of tenth magnitude, distance 70″.

ε Bootis. R. A. $14^h\ 41^m$; Dec. 27° 27′; magnitudes 3, 6·3; distance 2″·7; probably binary of long period; colors yellow and blue.

44 *Bootis.* R. A. $15^h\ 01^m$; Dec. 48° 01′; magnitudes 5, 6; distance 6″; binary of 261 yrs. period; magnitude and colors probably variable.

δ Bootis. R. A. $15^h\ 12^m$; Dec. 33° 39′; magnitudes 3·2, 7·4; distance 105″; colors yellow and blue; several other pairs and triplets in neighborhood.

μ Bootis. R. A. $15^h\ 21^m$; Dec. 37° 42′; magnitudes 4, 6·5; the smaller star is a double, magnitudes 6·7 and 7·3, distance 1″; this is a binary of 280 yrs. period, and probably revolves as a whole about the primary in a very long period.

δ Serpentis. R. A. $15^h\ 30^m$; Dec. 10° 51′; magnitudes 3, 4; distance about 4″; binary.

NOTE.—As a guide to the best performance to be expected from different telescopes under the best weather conditions the following table may be useful. It may be remarked, however,

that under ordinary conditions the performance will not be as good as indicated.

Diameter of Lens	Smallest Stars Visible	Closest Components Separable
1 inch	9·0 mag.	4″·5
2 "	10·5 "	2″·3
3 "	11·4 "	1″·5
4 "	12·0 "	1″·1
5 "	12·5 "	0″·9

Meridian Passage of the Principal Planets During May and June

LOCAL MEAN TIME

	For May 15		For June 15
Mercury	1.25 p.m.	Taurus	11.57 a.m.
Venus	12.15 p.m.	Aries, Taurus, Gemini	12.56 p.m.
Mars	6.16 a.m.	Capricornus, Aquarius	5.28 a.m.
Jupiter	6.57 p.m.	Leo	5.05 p.m.
Saturn	9.40 a.m.	Pisces	7.50 a.m.
Uranus	4.02 a.m.	Sagittarius	1.57 a.m.
Neptune	3.34 p.m.	Gemini	1.36 p.m.

Venus

Venus, which was in conjunction with the Sun on April 28, is now moving slowly to the eastward, but will not be at a sufficient distance from the Sun to be easily visible until towards the middle of June, when it may be seen low down in the western sky shortly after sunset.

Jupiter

Jupiter, which has been retrograding since the beginning of the year, ceases to do so and resumes its onward course on May 1. Its motion during May and June will, however, be so slight as to be barely noticeable in reference to the stars, being about 4½° to the east and 2° to the south. It continues to be favorably situated for observation during the greater part of that period, though towards the end of June it will be fairly low in the west. It is in conjunction with the Moon on the evening of May 26,

and again on the morning of June 23, being on both occasions several degrees to the south.

Mercury

Mercury is an evening star until June 14; then a morning star. It is at its greatest elongation east on May 20, and is most favorably situated for observation after that date, when it may be looked for low down in the western sky, and nearly over the point where the Sun has set.

Mars and Saturn

Both these planets may now be seen in the early morning sky, Mars somewhat to the east of the meridian, and Saturn further to the east. The two planets are approaching each other, though still a considerable distance apart. On June 1 Mars will rise shortly before one o'clock, and Saturn shortly after two. They are in conjunction with the Moon on June 10 and June 13 respectively, both being slightly to the north.

Eclipses

During the month of June there will be two eclipses, one of the Sun and one of the Moon.

I.—A total eclipse of the Moon, June 3, partly visible throughout Ontario and Quebec, the Moon rising eclipsed; practically the whole eclipse will be visible in the Maritime Provinces, and only the end in Manitoba.

CIRCUMSTANCES OF THE ECLIPSE:—

Moon enters penumbra	5.36 p.m.	
Moon enters shadow	6.43 "	
Total eclipse begins	7.58 "	Eastern
Middle of the eclipse	8.29 "	Standard
Total eclipse ends	9.00 "	Time
Moon leaves shadow	10.14 "	
Moon leaves penumbra	11.21 "	

First contact of shadow with Moon's limb, 125° East of North.
Last " " " " " " 99° West " "
Magnitude of the eclipse = 1·164 (Moon's diameter = 1·0).

Moon rises at Ottawa 7.36 p.m. Eastern Standard Time.
" " " Toronto 7.45 p.m. " " "

II.—A central eclipse of the Sun, June 17, visible throughout Ontario and Quebec as a partial eclipse, the Sun setting eclipsed. West of the Great Lakes it will be completely visible as a partial eclipse. The line of totality runs from Siberia over the North Pole, and ends at the southern extremity of Greenland. At the extremities of this line it will be an annular eclipse, over the remainder a total eclipse.

The following circumstances have been very kindly supplied by A. M. W. Downing, Director of the Nautical Almanac Office.

At Ottawa a partial eclipse is partly visible, magnitude ·601 (Sun's diameter = 1).

Eclipse begins	6.52 p.m.
Greatest phase	7.43 "
Sun sets	7.50 "

Angle of first contact from north point, 294° towards the east. Angle of first contact from vertex, 250° towards the east.

At Toronto a partial eclipse is partly visible, magnitude ·540.

Eclipse begins	6.57 p.m.
Greatest phase	7.48 "
Sun sets	8.00 "

Angle of first contact from north point, 298° towards the east. Angle of first contact from vertex, 251° towards the east.

Trans-Neptunean Planet

For various hypothetical reasons, Professor W. H. Pickering and Professor Forbes, have independently predicted the existence of a trans-Neptunean planet about one hundred times farther from the Sun than the earth. The hypothetical position assigned to it by Professor Forbes would be at about 2° N. W. of the star cluster ω *Centauri*, R. A. $13^h\ 12^m$, Dec. $-45°$, some 30° S. of Spica the bright star in Virgo, with the plane of its orbit inclined about 45° to the ecliptic; whilst Professor Pickering would place it in R. A. $7^h\ 12^m$, Dec. $+21°$, about 10° S. of Pollux in Gemini, near the ecliptic. Such a body has not yet been found though newspaper reports to that effect have been seen abroad.

Date 1909	Day of Year	The Sun's Right Ascension	The Sun's Declination	Equation of Time (add to Mean Time)	Sidereal Time
		h m s	° ′ ″	h m	h m s
Sat. 1	121	2 32 09·53	N. 14 57 58·9	2 55·88	2 35 05·41
Tues. 4	124	2 43 38·26	15 51 33·5	3 16·81	2 46 55·07
Fri. 7	127	2 55 11·94	16 42 46·1	3 32·80	2 58 44·74
Mon. 10	130	3 6 50·78	17 31 28·9	3 43·63	3 10 34·41
Thur. 13	133	3 18 34·93	18 17 34·9	3 49·15	3 22 24·08
Sun. 16	136	3 30 24·42	19 0 55·7	3 49·32	3 34 13·74
Wed. 19	139	3 42 19·12	19 41 23·8	3 44·29	3 46 3·41
Sat. 22	142	3 54 18·80	20 18 51·3	3 34·28	3 57 53·08
Tues. 25	145	4 6 23·16	20 53 10·6	3 19·59	4 9 42·75
Fri. 28	148	4 18 31·87	21 24 16·0	3 0·56	4 21 32·43
Mon. 31	151	4 30 44·63	21 52 0·8	2 37·47	4 33 22·10

75th Meridian Time, Hours numbering from Midnight

		Planetary Phenomena	Minima of Algol	Configuration of Jupiter's Satellites at 22h 30m
			h m	
	Sat, 1	19h ♃ Stationary.	3 59	21○34
	Sun. 2			342○1
	Mon. 3			341○2
	Tues. 4		0 48	432○1
☉	Wed. 5	12h 16·1m Full Moon.		421○●
	Thur. 6		21 37	24○23
	Fri. 7			4○123
	Sat. 8			421○3
	Sun. 9	9h ☿ Greatest Heliocentric Latitude N.	18 26	432○1
	Mon. 10	10h 38m ☌ ♅ ☾, ♅ 2° 29′ N.		31○2●
	Tues. 11	15.		24○314
☾	Wed. 12	15h 27m ☌ ♂ ☾, ♂ 2° 56′ N.; 21h 53·6m Last Quarter.	15 15	21○4●
	Thur. 13	10h □ ♂ ☉.		○1234
	Fri. 14			○234●
	Sat. 15		12 04	12○34
	Sun. 16	13h 40m ☌ ♄ ☾, ♄ 2° 25′ N.; 20·6h ☾ in Perigee.		32○14
	Mon. 17			31○24
	Tues. 18		8 53	24○31
●	Wed. 19	13h 50·3m New Moon; 18h 34m ☌ ☿ ☾, ☿ 1° 6′ N.		2413○
	Thur. 20	11h ☿ Greatest elongation E., 22° 23′.		4○123
	Fri. 21	1h 35m ☌ ☿ ☾, ☿ 1° 40′ N.	5 42	4○23●
	Sat. 22	5h ♀ in ♌; 19h 10m ☌ ♆ ☾, ♆ 3° 13′ S.		421○3
	Sun. 23			423○1
	Mon. 24		2 31	431○2
	Tues. 25			43○21
	Wed. 26	18h 05m ☌ ♃ ☾, ♃ 4° 13′ S.	23 20	2143○
☽	Thur. 27	1h 36·1m First Quarter; 6h □ ♃ ☉.		○413●
	Fri. 28	17·5h ☾ in Apogee.		1○243
	Sat. 29		20 08	24○231
	Sun. 30			23○14
	Mon. 31			31○24

Key to Symbols.—☌ Conjunction; ☍ Opposition; □ Quadrature; ☊ Ascending Node; ☋ Descending Node; ☉ Sun; ☿ Mercury; ♀ Venus; ⊕ Earth; ♂ Mars; ♃ Jupiter; ♄ Saturn; ♅ Uranus; ♆ Neptune.

JUNE

Date 1909	Day of Year	The Sun's Right Ascension	The Sun's Declination	Equation of Time Add to / Sub't from Mean Time	Sidereal Time
		h m s	° ′ ″	m s	h m s
Tues. 1	152	4 34 49·71	N. 22 0 30·4	2 28·94	4 37 18·66
Frid. 4	155	4 47 7·31	22 23 40·5	2 1·02	4 49 8·33
Mon. 7	158	4 59 28·12	22 43 19·7	1 29·88	5 0 58·00
Thur. 10	161	5 11 51·76	22 59 24·5	0 55·91	5 12 47·68
Sun. 13	164	5 24 17·72	23 11 51·6	0 19·63	5 24 37·35
Wed. 16	167	5 36 45·40	23 20 38·5	0 18·38	5 36 27·02
Sat. 19	170	5 49 14·08	23 25 43·1	0 57·38	5 48 16·70
Tues. 22	173	6 1 43·01	23 27 4·3	1 36·64	6 0 6·37
Fri. 25	176	6 14 11·46	23 24 42·2	2 15·42	6 11 56·04
Mon. 28	179	6 26 38·78	23 18 37·4	2 53·06	6 23 45·72
Thur. 31	182	6 39 4·34	23 8 51·8	3 28·95	6 35 35·39

75th Meridian Time, Hours numbering from Midnight

		Planetary Phenomena	Minima of Algol	Configuration of Jupiter's Satellites at 21h 30m
			h m	
Tues.	1	20h ☿ in ♉.	16 57	3○214
Wed.	2	12h ☿ Stationary.		231○4
Thur.	3			2○134
♈ Fri.	4	1h 33·0m Full Moon.	13 46	2|1○23
Sat.	5			42○13
Sun.	6	15h 35m ☌ ♁ ☾, ♁ 2° 29′ N.		42○3●
Mon.	7	10h ☌ ☿ ♀, ☿ 2° 11′ S.	10 35	431○2
Tues.	8			43○12
Wed.	9			4321○
Thur.	10	2h 53m ☌ ♂ ☾, ♂ 2° 33′ N.	7 24	42○31
☾ Fri.	11	2h 50·9m Last Quarter.		41○23
Sat.	12	2h ☿ in Aphelion; 16·4h ☾ in Perigee.		2|4○13
Sun.	13	1h ☌ ♄ ☾, ♄ 2° 13′ N.	4 13	21○3●
Mon.	14	18h ☌ ☿ ☉ Inferior.		2|3○24
Tues.	15			3○124
Wed.	16		1 02	321○4
♈ Thur.	17	11h 13m ☌ ☿ ☾, ☿ 4° 29′ S.; 23h 36·6m New Moon.		2○314
Fri.	18	20h 58m ☌ ♀ ☾, ♀ 1° 08′ S.	21 51	1○234
Sat.	19	5h 54m ☌ ♆ ☾, ♆ 3° 17′ S.		○2134
Sun.	20			21○34
Mon.	21	21h 05·9m ☉ enters Cancer; summer begins.	18 40	34○1●
Tues.	22			34○2●
Wed.	23	1h ☌ ♀ ♆, ♀ 1° 52′ N.; 7h 57m ☌ 2| ☾, 2| 4° 21′ S.		4321○
Thur.	24	23h ☿ in Perihelion.	15 29	42○1●
☽ Fri.	25	12·3h ☾ in Apogee; 14h 51·1m First Quarter.		41○23
Sat.	26	12h ☿ Stationary.		4○213
Sun.	27		12 18	421○3
Mon.	28			43○1●
Tues.	29			34○2●
Wed.	30		9 07	321○4

For Jupiter's Satellites, the circle ○ represents the disc of the planet; 2| signifies that the satellite is on the disc; ● signifies that the satellite is behind the disc or in the shadow. Configurations are for an inverting telescope.

ECLIPSES AND TRANSITS OF THE SATELLITES OF JUPITER

E = eclipse, O = occultation, T = transit, S = shadow, D = disappearance, R = re-appearance, I = ingress, e = egress.
Eastern Standard Time; hours numbering from noon.

MAY

d	h	m			d	h	m			d	h	m		
2	8	42	IV.	SI	**11**	9	50	II.	SI	**20**	10	18	II.	ER
	10	42	II.	OD		10	12	II.	Te	**21**	10	07	I.	OD
	12	43	IV.	Se		12	40	II.	Se	**22**	8	43	I.	SI
4	7	41	II.	Te	**12**	8	31	III.	OD		9	45	I.	Te
	10	04	II.	Se		12	01	III.	OR		11	01	I.	Se
5	8	12	III.	OR	**13**	7	43	II.	ER	**23**	8	08	I.	ER
	9	41	III.	ED		11	04	I.	TI		10	59	III.	Se
	11	52	I.	OD		12	19	I.	SI	**25**	12	28	II.	TI
	12	52	III.	ER	**14**	8	13	I.	OD	**28**	12	01	I.	OD
6	9	12	I.	TI		11	44	I.	ER	**29**	9	21	I.	TI
	10	24	I.	SI	**15**	7	52	I.	Te		10	37	I.	SI
	11	31	I.	Te		9	06	I.	Se		11	40	I.	Te
	12	43	I.	Se	**18**	9	52	II.	TI	**30**	9	56	III.	Te
7	9	49	I.	ER		12	27	II.	SI		10	03	I.	ER
9	13	12	II.	OD		12	44	II.	Te		11	40	III.	SI
10	11	40	IV.	OR	**19**	12	24	III.	OD					

JUNE

d	h	m			d	h	m			d	h	m		
3	10	10	II.	OD	**12**	9	57	II.	Te	**19**	9	46	II.	TI
4	8	39	IV.	TI	**13**	10	23	I.	OD	**21**	9	39	I.	TI
5	9	49	II.	Se		10	54	IV.	ER		9	55	II.	ER
	11	16	I.	TI	**14**	8	56	I.	SI		10	50	I.	SI
6	8	26	I.	OD		10	01	I.	Te	**22**	10	17	I.	ER
	10	29	III.	TI		11	14	I.	Se	**24**	8	46	III.	OD
7	8	04	I.	Te	**15**	8	22	I.	ER	**29**	8	49	I.	OD
	9	19	I.	Se	**17**	8	03	III.	OR	**30**	8	25	I.	Te
10	8	46	III.	ER		9	39	III.	ED		9	31	I.	Se
12	9	37	II.	SI										